CANNING PRACTICE AND CONTROL

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To

JOHN FRANCIS BODINNAR, ESQ., J.P.

Behold the weapons man has wrought
  Against his foes in flesh that bide
And multiply—behold, in short,
  The ardours of bactericide.

PREFACE

In presenting this volume to the canning public the authors are fully aware of many of its imperfections, although possibly time only will reveal the whole of them. Their aim has been to put together a book of practical value that would include those items of information the canner needs if he is to put on the market a properly processed foodstuff. They have tried to keep continually in mind the terms of the book's title, and to adhere to them in spite of many a temptation to turn aside to other forms of packing. The definition of canned food that has been adopted is that of "foodstuff hermetically sealed and processed in a metal container." This includes fruits, fish, vegetables, and meats, but not powders and other dry solids such as milk, biscuits, cocoa, coffee, etc., sealed in tinplate containers, nor does it include foodstuffs processed in glass containers. It is true that many of the considerations to be taken account of in the last are identical with those affecting canned foods *per se*, but from several aspects the technology varies.

Canning may be briefly described as filling the metal container with food and sauce, syrup, soup, brine or gelatine, exhausting it of air, sealing on a lid, sterilising the can and its contents, and finally cooling them. This is the essence; its elaborations form the subject matter of this book.

In selecting their material from personal experience, and from the scattered literature on the subject, the authors have attempted to include matters of direct practical service to the canner, or would-be canner. Much of purely academic interest, particularly in regard to the chemistry of foodstuffs in general, has been deliberately omitted. That is available in the technical literature and in standard works. It has not been their object to compile a treatise, but rather a bench book, although some may consider the interpretation of the latter term rather liberal in certain directions, as, for example, in parts of Chapter II, Chapter IV, and Chapter XII.

It will be found that principles have been stressed, and only amplified in detail where it seemed that detail was required. This is particularly true of the analytical chapters. The analytical methods discussed apply only to those substances likely to be handled in the canning factory, and further, in many cases only one method of analysis is given for a particular determination. For the majority of substances, there are many different analytical schemes, and to include even a fraction of them would have meant a departure from the real intention of the work. For this reason

the only methods given are those which have been well tried in the canning laboratory and found satisfactory. Again, in those chapters dealing with mycology, only those organisms are described which are almost certain to be met with in practice ; to attempt to include the morphological characteristics of all the bacteria that might be found would involve a special work upon bacteriology.

The industry is one that is only now growing out of the rule of thumb stage into something approaching an applied science. It is young enough to be continually critical of the few conventions it has established, and to criticise them and suggestions of new ways in the light of new problems daily confronting it. The diversity both in substance and kind, of the foods packed to-day is immense : their name is legion, but probably few compared with those the near future will produce. Some indication of the legion may be gathered from the inadequate statistics collected together in the first chapter.

The keeping qualities of canned foods should be well known by now. In some contracts, the canner finds it necessary to guarantee that the food will keep in prime condition for at least two years. One of the authors recently had occasion to open a can of meat processed in 1881, and found it to be in perfectly good condition, not even being discoloured, and as appetising as the day it was sealed. The value of stocks of canned foods in times of stress has been verified in every successive war since Nicholas Appert won Napoleon's prize for a method of preserving food so that it would keep, and could be easily transported.

The expansion of canning capacity in this country during the World War of 1914–1918, is well known, although it is not equally realised how great was the increase in imports as well. There are those who advocate the laying down of adequate stocks against another emergency. The country should be provided with " iron rations." The dimensions of such a stock should not be beyond computation, in view of the figures we have concerning the consumption between 1914–1918, and the comparison between the population then and now. Probably, the more valuable form of stocks should be meat and fish. Cereals have their own keeping qualities, and may be relied upon to provide the necessary carbohydrates. Protein and fat are not so easily stored unless they have been adequately preserved and hermetically sealed.

It was noticeable that, during the War, the imports of canned foodstuffs showed a decline as regards fruit, but an increase in so far as protein and fats—namely fish, meat and milk—were concerned. The canned fruit imported in 1918 was only 49 per cent. of that of 1913, whereas the meat was 246 per cent., fish was 145 per cent. and milk 205 per cent. One or two other facts show how the country, "guided " by the Food Controller, forsook luxuries, but concentrated upon necessities.

Whilst the quantities of canned lobsters were halved, the "unenumerated varieties " of canned fish increased four times. Separated and skimmed

milk fell to one-third whereas whole milk increased more than four times. The privations of the War were interestingly underlined by the extraordinary jumps in imported canned foods in 1919 when not only were the difficulties of sea-borne transport removed, but economic stringency was diminished. The 1918 importation of canned fruit was multiplied by six, whilst meat and milk showed approximately 50 per cent. increases. In fact the 1919 figures for imports of canned foods were the highest this country has ever seen and only in 1935 did the market expand to anything approaching equality. It would seem that a stock large in comparison with the wartime stock could be carried without dislocation of the canned foods markets.

Finally, to return to our opening theme, the authors hope that this volume will fill a want. They have recognised for some time that a book of this scope was needed, but they must confess to a lack of appreciation of the urgency of the need until a series of articles " The Bacteriology of Canning," a title useful though not strictly accurate, had been published in *Food*. The reception accorded that series by canners all over the world, and the speed with which the issues concerned ran out of print has decided them to put them in a more permanent form, and to add other pertinent material.

To the proprietors of that journal, The Nema Press, Ltd., they would acknowledge their indebtedness for permission to allow those articles to reach this present form, and for their permission to utilise illustrations from that journal, and to the St. Margaret's Technical Press, Ltd., for illustrations from the *Industrial Chemist*. To Messrs. C. and T. Harris (Calne), Ltd., ready acknowledgment is rendered for facilities too numerous to describe. The authors would also record their appreciation of permission given to reproduce other photographs by the commercial organisations whose names appear below them. It is felt that record should be made of the fact that the unique set of micro-photographs was made by Mr. J. G. Bradbury, F.R.M.S., F.R.P.S. They also desire to place on record their indebtedness to Sir J. Boyd Orr, and to the Market Supply Committee for granting facilities for checking certain of the statistical matter in the first chapter, and for other figures to the Commercial Secretary of the British Legation at Berne, the Commercial Attaché of the American Embassy in London, the High Commissioner for New Zealand, and the Danish Consul General in London.

Finally the authors are indebted to Dr. J. Hoy Robertson, B.Sc., A.I.C., Dip.Chem.E., for reading certain chapters, and to Mr. Eric Chilman for the dedication at the front of the book.

<div align="right">O. J.
T. W. J.</div>

CONTENTS

xi

CHAPTER I

SOME PRELIMINARY STATISTICS .

IT is said that about 1804 a Frenchman, Nicholas Appert, invented a method for preserving foods by sealing them hermetically in containers in a sterile condition, thereby winning a prize offered by the first Napoleon and founding an industry that to-day is an important factor in the food supply of the world. It is also said that it was an Englishman, Peter Durand, who first used tin-plated steel containers for this purpose.

One hundred and thirty years later, the population of the United Kingdom spent about 12s. 5d. per head per annum upon canned foodstuffs. This was spent out of an average annual expenditure of £23 8s. per head upon food of all kinds. For this small sum the kinds of food obtainable at any given moment in canned form are far more diversified than is the choice of raw food. Canned food may be eaten out of season and out of place.

This figure is correct to within a penny or so. Those who like their figures in greater detail may refer to the following summary and the sources whence this total was calculated.

United Kingdom Consumption and Production

The most recent year for which canned food consumption in the United Kingdom can be calculated is 1934. Although the foreign trade figures— imports and exports—are available for the years 1935 and 1936, the figures of production within the country are only obtainable up to and including 1934. It is not expected that the 1935 Census of Production figures will be available until some time after this volume is published.

Taking the figures of production[1] for 1934, it will be found that canned meat is given as valued at £2,082,000 ; of fish, as £321,000 ; milk, £3,467,000 ; fruit, canned and bottled, £1,594,000 ; and vegetables, £1,837,000. These, adjusted by importation and export figures from the Trade and Navigation[2] returns for 1934, will give the consumption. Imports of meat were valued at £4,452,000 ; of fish, £6,433,000 ; of milk, £2,808,000 ; of fruit, £5,378,000 ; and vegetables, £936,000. Exports and re-exports of meat were given as £75,000 ; of fish, £535,000 ; and of milk, £466,000 ; the exports of fruit and vegetables being too small to affect the figures. These, by simple arithmetic, give a consumption in this country in 1934 of £6,459,000 of canned meat, £6,219,000 of

fish, £5,809,000 of milk, £6,972,000 of fruit and £2,773,000 of vegetables : a grand total of canned foods of £28,232,000.

The figures must be accepted with caution : they are not strictly accurate. The production figures include meat in glass as well as in tinplate cans, meat and fish paste in glass, bottled fruit, soup squares and soup powders. The export figures omit canned fruit. On the other hand, they are sufficiently accurate to enable one to place canned foods in perspective as an item in the national dietary.

United Kingdom Imports

They also bring out the fact that with canned foods, as with other foods, the United Kingdom is a greater importer than a producer, importing more than twice as much as she produces, and has but little *entrepôt* trade. Her imports are about five-sevenths of her consumption. She is, in fact, the greatest importer of canned food in the world. Of canned meat she took in 1933[3] 68 per cent. of the exports of the Argentine, 59 per cent. of those of Uruguay, 78 per cent. of those of the United States and 49 per cent. of the Australian. Although the production of condensed milk in the U.K. has expanded considerably since the introduction of the Milk Marketing Schemes, she was, in 1934, still the largest importer in the world in spite of the drop in all varieties since the peak year of 1931. Although the United States of America is the largest user of canned fruits preserved in syrup, the United Kingdom is the largest importer in the world. Although imports in 1934 were higher than ever before, they were beaten in 1935 at 3,691,000 cwts. The Empire share of this trade has steadily increased of recent years and in the five years, 1929-33, reached 35 per cent., 70 per cent. of it being pineapples from Malaya.

As an exporter the United Kingdom occupies, as would be expected, a lowly place. Exports and re-exports of canned foods totalled, in 1934, only 388,000 cwts., valued at £1,176,000. These consisted of 7,000 cwts. of home canned meat, 223,000 cwts. of condensed milk and 73,000 cwts. of fish : exports of imported canned foods consisted of 14,000 cwts. of meat and 70,000 cwts. of fish. The exports of canned and bottled fruit, in 1933, were 9,000 cwts. and canned and bottled vegetables 20,000 cwts.

Chief Foods Consumed

` A few more figures will serve to distinguish between the more important classes of canned foods consumed. They must be read with the reservations suggested above, but are substantially true for 1934. In quantity and value, canned and bottled fruits held pride of place at 4,157,000 cwts. and £6,972,000. Next in quantity came milk at 3,694,000 cwts. and £5,809,000, but next in value came meat at £6,459,000 and 1,530,000 cwts.;

fish figures were 1,538,000 cwts. and £6,219,000, nearly the same in weight with meat and nearly the same in value. (The lowness of the milk value per cwt. was accounted for by the large imports of condensed separated milk.) But to the meat and fish figures must be added those for the United Kingdom production of meat and fish paste in tins and bottles of 125,000 cwts., valued at £1,259,000; this gives a truer picture of the consumption of these two kinds of food, although one must allow for the utilisation of some canned meat and fish in their respective pastes. The vegetable consumption was, however, higher than either meat or fish, although much smaller in value, the figures being 1,847,000 cwts. and £2,773,000.

Beef was the chief imported meat and salmon the chief fish. No one meat was singled out in the production figures, but herrings predominated among home canned fish. Plums were the principal home canned fruit and peas the vegetable. Peaches, pears, and pineapples continued to be the favourites among imports, although fruit salad, grape fruit and orange showed an increase : the popularity of the apricot is definitely waning.[4] The contraction in imported currants and berries are ascribed[4] as due to the growth of the United Kingdom canning industry. Imported plums, currants, and berries are suggested as being supplementary to the home produced commodities rather than being the only source of supply, as is true of other fruits. Among imported vegetables the tomato reigned supreme, the imports being nearly ten times the quantity of all other vegetables put together.

Growth of United Kingdom Canning

The Report on the Import Duties Act Inquiry (1933)[5] made some interesting comparisons that indicate the movement in canning in the United Kingdom between the year of the Third Census of Production, 1924, and ten years later. It showed also the 1930 figure, that of the Fourth Census of Production. Taking the output of 1930 as 100, production of meat in tins and glasses rose from 97 in 1924 to 114 in 1933 ; of canned fish fell from 113 to 94 ; meat and fish paste in tins and glasses rose from 63 to 115 ; canned or bottled fruit in syrup from 33 to 207 ; the same without sugar from 47 to 127 ; vegetables from 14 to 334 ; condensed milk from 96 to 111. The considerable growth in fruit and vegetables has not been unaccompanied by difficulties of one kind and another, among the chief of which must be ranked growing and marketing.

According to a Ministry of Agriculture inquiry, there were in the United Kingdom, in 1922, some three firms engaged exclusively in fruit canning, and seven others combined canning with bottling. By 1927, according to H. C. Gill,[6] there were twenty canneries established in the United Kingdom, and by the end of 1931, fifty-nine. Two years later[4] there were eighty-three, of which fifty-four were registered packers under the

National Mark.   In 1934 these figures had shrunk to eighty and fifty respectively.   Only one new factory was erected in 1934, and four existing ones did not operate.   The tendency continued in 1935, the total number of factories engaged on fruit and vegetables falling to seventy-three.[8] A sufficient indication of the reaction to too rapid growth, coupled with the consequences of the Great Depression, as the slump of 1930-1934 has been christened.   Even without the Great Depression, it was however obvious that manufacturing capacity would have had to slow down.   Although marketing difficulties were not wanting, there were the technical ones of the little known vagaries of British crops and weather, and the lack of experienced operatives.

The growth of the United Kingdom canning industry has of recent years been undoubtedly facilitated by the assistance of various organisations, some of a purely technical, and others of a marketing, nature. Applied science has benefited it through the work of the Fruit and Vegetable Preservation Research Station, Campden, the Low Temperature Research Station, Cambridge, and the British Association of Research for the Cocoa, Chocolate, Sugar, Confectionery and Jam Trades.   All three are under the wing of the Department for Scientific and Industrial Research, the first by way of the canning and allied trades, the University of Bristol and the Food Investigation Board, and the second, the Food Investigation Board and the University of Cambridge, the last of the three being by way of the British Food Manufacturers' Federation. The National Mark Scheme has been prepared by the Ministry of Agriculture and Fisheries, the Food Canning Council and the National Farmer's Union.   In addition, valuable work upon tinplate is being carried out by the International Tin Research and Development Council.

Canning Figures of Other Countries

The canning figures for the United Kingdom should be compared with a few of those available for other parts of the world.   In the United States of America, according to the 1931 Census, there were 2,535 establishments.   In 1933, as might be expected, in view of the economic situation, this figure had fallen to 2,069.   The gross value of the output also fell from $513,000,000 in 1931 to $438,821,000 in 1933.   The 1934 total was somewhat greater.   The Pacific Coast States form the most important fruit canning area in the world, the record pack of 1928 being just under 28,000,000 cases of fruit.   The aggregate fruit pack of the American industry in 1934 was 33,000,000 cases, equivalent to about 12,000,000 cwts.   Japan has a rapidly growing industry, the total pack of all foods in 1935 being over 8,500,000 cases.

The production of canned vegetables in Germany in 1933 was, according to the Food Division of the U.S.A. Department of Commerce, equivalent to 85,000,000 cans of No. $2\frac{1}{2}$ can, and of fruit 26,500,000 cans.

This increased in 1935 : the value being 138,000,000 marks. The Australian fruit pack in 1934 was 1,427,517 cases on a basis of 24 No. 2½ cans per case. The Hawaiian pineapple pack in 1934-5 was 9,600,000 cases. The South African production in 1933 was 12,941,855 lbs. The Japanese production of fruit in 1934 was 1,733,653 cases, and of vegetables 756,848 cases. The Canadian pack of asparagus, spinach, peas, rhubarb and apricots totalled 1,484,510 cases in 1934. The Canadian fruit pack the year before, 1933, was about one million cases, and of all vegetables about four million. The canned vegetable production of France in 1934 was about three million cases and half a million of fruits. The Dutch pack of fruit and vegetables totalled some 45 million cans in 1934. The Italian fruit and vegetable pack is estimated[2] at over 100,000 tons. The pack of Swedish canned vegetables is given[7] for 1932 as three and a half million kilogrammes, the pack of Danish vegetables four and a half million, Belgian vegetables 403,000 cases and Swiss fruit 22 million cans.

Then with regard to meat and fish there are a few interesting statistics available. The United States output of canned meat in 1933 was 137,290,000 lbs., valued at $18,990,000, and the production of canned sausage in the same year was 12,336,000 lbs., value $1,709,000. The Canadian meat pack in 1934 reached a weight of 3,198,307 lbs. Japanese meat and dairy products were 1,038,229 cases. But the largest item in the Japanese canned food pack in 1934 was marine products at 4,267,113 cases, the chief items being salmon and sardines in tomato. Korea is developing as a fish canning area. According to the United States Department of Commerce, there were 74 canneries operating there in 1934, giving a pack of 233,558 cases. In the Argentine, the home of canned beef, there were 12 establishments canning fish in 1934, giving a product of 2,273,260 lbs., and some 28 canneries processing tomatoes.

The French meat pack[7] in 1933 was 600,000 cases. German fish, in 1933-4, 6,600,000 marks ; Norwegian fish, in 1932, 46,743 tons and Norwegian meat, 1,018 tons ; Swedish fish, in 1932, 11 million kilogrammes ; and Danish fish, in 1933, over 1 million kilogrammes and meat 5 million.

In 1934 the Canadian pack of condensed whole milk totalled 68 million lbs. New Zealand figures for production of condensed milk are not available. According to information privately supplied by the office of the High Commissioner in London, statistics regarding the production of " butter, cheese and condensed milk " are given under the one heading and, although the amounts of butter, whey butter, and cheese produced by such factories are shown separately, all other products of the factories are shown under the general designation " other products." The total value of " other products " in ten years ended March 31st, 1935, was £862,040 N.Z. That condensed milk would not be the most important item in this figure may be indicated by the export figures for milk in 1934. Preserved and condensed milk (other than dried) exports were 4,069,328

lbs., valued at £69,169 N.Z. The dried milk (full cream) figures were 5,161,813 lbs., £182,527 N.Z., and other dried milk 12,331,309 lbs., £156,012 N.Z.

The milk figures for Denmark, privately supplied by the Danish Consulate General, London, for 1934, were condensed full milk sweetened, 6,100,000 kg. ; unsweetened, 4,300,000 kg. ; and skimmed sweetened, 9,200,000 kg. ; homogenised sterilised cream, 2,400,000 kg.

Swiss figures for milk processed in 1934 in factories were 18,000 tons, the production of condensed and powdered milk being given as a joint total of 6,400 tons, and the exports of condensed milk 5,939 tons.

To extend these figures would serve little purpose, as the statistics necessary are not available to make an adequate survey of the canned food production of the whole world. In only too many instances figures of production are lacking and in others they are not to be had in comparable form. The diversity of size of can is one militating factor, another is the variation in quantity of foodstuff packed in various cans. The figures that have been quoted are sufficient to give relationship to the British figures and indicate, perhaps not as fully as might be desired, the widespread utilisation of the hermetically sealed can as a container for perishable foods.

International Trade and Regulations

It is not surprising that canned foods should prove no exception to the extensive regulation of the substances, that may or may not be added to foodstuffs, imposed in the interests, and supposed interests, of the consumer.

In those cases where canned foods are being packed for export, the reader is advised to familiarise himself with the standards demanded by the different countries. Frequently they include stipulations in regard to permissible amount of starch in meat products, wording of the labels, permitted colours, etc., etc. As the regulations are more or less continually under revision, no useful purpose would be served by quoting them *in extenso* here. The best course is to communicate with the appropriate consular office in England or with the Department of Overseas Trade.

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THE CANNERY AND PRELIMINARY EQUIPMENT

BEFORE describing the canning process and the equipment involved, it is only fitting to consider the preliminary operations and the cannery itself. Both preliminary operations and the nature of the product canned affect not only the equipment required but also the type of building usually constructed for the purpose. For example, vegetables and fruit set much the same problems, milk is a raw material unlike any other food-stuff that is canned, and although meat and fish are not dissimilar their preparation for the can involve processes that are poles apart.

Canneries for vegetables, fruit and milk, in view of the rapid deterioration of the food, are usually situated close to the source of supply. Meat canneries are usually adjacent to plant handling meat in bulk for other purposes, and may be hundreds of miles from the grazing areas. Fish canneries are necessarily in or near the fishing ports.

The erection of a factory of any kind involves consideration of two types of costs, investment and operating. Under the heading of investment costs may be placed all those items involving the factory itself, such as the purchase of the site, its surveying and planning, the purchase and erection of the plant upon it, the building of the factory, and so forth. Operational costs include the cost of labour, raw material, transport, processing, storage and distribution. Under this heading also should come maintenance of plant and buildings. Where operating costs are high compared with selling prices, then it will be found that investment costs are kept as low as possible, and where operating costs are proportionately low then it will be found that more expensive and permanent buildings are erected. This generalisation is more than amply demonstrated in the canning industry, not only in this country but in the great canning continent, America. Where the factory is producing for only short periods, as in fruit and vegetable canning, then lightly constructed buildings of one storey predominate, whilst when the factory is able to operate all the year round, as in meat canning, then the building is of solidly built multi-storey construction. The moral is pointed even more certainly when the value of the product is considered. Taking the values per hundredweight given in the Report on the Import Duties Act Inquiry (1933) (the detailed 1934 figures are not yet available), the value of " Preserved meat in tins, glasses, etc.," was £7·15 per cwt., of " Canned
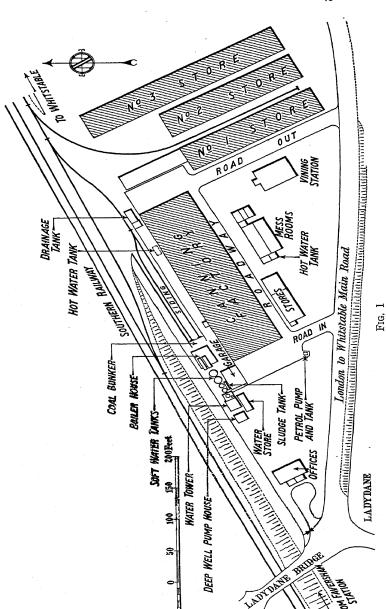
and bottled vegetables " £1·81, of " Fruit without sugar, canned or bottled " £2·26, of " Fruit in syrup, canned or bottled " £2·54, of " Condensed milk, sweetened, whole " £2·75, and of " Condensed milk, separated or skim " £1·23.   It is not surprising therefore that, whilst the modern canned meat factory is a substantial edifice, the pea or peach cannery is far more flimsy in construction.

The operations that have to be performed in any canning factory are those of the preparation of the raw material for processing, and the making of the cans.   Next comes the filling of the cans, followed by exhausting, closing, processing or sterilising, cooling, labelling and boxing.   Warehouse accommodation is also required either before or after labelling and boxing.   It is therefore obvious that the movement of raw materials, materials being processed, and finished products, will be one of the main operating charges.   In mass production this must be achieved by the cheapest force possible, and that is gravity.

Single- Versus Multi-Storey

The single-storey building is the cheaper in original cost because the high cost of floor and roof is offset by the elimination of those expensive items, stairs and lifts ; furthermore, the structural problem is relieved of the increased cost necessitated by live load design.   The bearing value of the soil is enormous and the weight of plant in a single storey building is not a factor that needs much consideration.   But still more important, these investment costs are assisted by reduced maintenance and operating costs.   Stitt[1] claims that single-storey design conserves about 20 per cent. of the employees' operating time.   On the other hand, the single-storey building renders it difficult to utilise gravitational flow, and it is interesting to observe what ingenious shifts are adopted to try to make the best of both worlds in fruit and vegetable canning.

One of the cleverest is undoubtedly the Lady Dane Cannery at Faversham in Kent.   Advantage was taken of the fall of a gentle hillside.   We will, for the moment, neglect the other desiderata of the site and analyse it purely in terms of its utilisation of gravity.   The ground slopes from the left downwards to the right in the line drawing, the whole being on a slight incline downwards towards the railway.   In the left-hand corner of the triangular site have been erected the water tanks and the water treatment plant.   Next down the hill is the canning factory proper.   Since the major portion of the peas and fruit are delivered by road, the vining station is sited above the canning factory level and the peas are delivered to the factory by an overhead flume.   Peas and fruit pass through their processes down the factory from left to right and the canned product flows by a system of roller conveyors to the three warehouses, which are situated at the lowest point of the site.   No. 1 warehouse houses the labelling and packing plant, Nos. 2 and

FIG. 1

LAY-OUT OF THE LADY DANE CANNERY

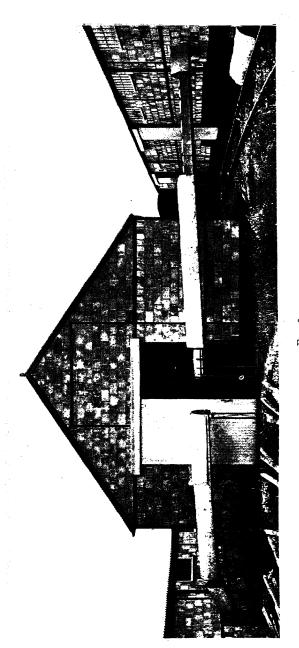*Courtesy of Burt, Boulton & Haywood, Ltd., and " Food"*

3 are merely storehouses. Between the three the roller conveyors permit the cans to be retained and handled in No. 1, or allow them to pass on to the other two for storage in either of them, the roller system connecting up with a track down the centre of each building. For return to No. 1 from Nos. 2 and 3 for packing and labelling, there is another conveyor that passes them back at the upper end of the buildings. Warehouse No. 1 being the labelling, packing and despatch building, it is bounded on one side by a roadway and on the other by a railway siding, elevation of the packed product to truck or lorry being achieved by means of mobile inclined conveyors driven by $1\frac{1}{2}$ h.p. motors. The canning factory has been built with a small second storey at the centre, and this provides space for the can store and syrup pans. Sugar and empty cans are elevated to it from the railway siding by electrically operated conveyors. The cans are fed as required to the filling belt in the canning factory, and the syrup flows by gravity to the syrupers.

An example of the internal construction of false floors within a single-storied building is well shown in the illustrations to an article[2] by V. Cahalin on " Canning Peaches and Fruit Salad in California." where platforms have been erected alongside syrup pans, grading, washing and can-making plant, all of which are situated above floor level to obtain sufficient fall for gravitational movement from process to process.

The sardine canning area of Northern California is the most important and most highly developed in the world, the annual pack being about two million cases. It, like fruit and vegetable canning, is a seasonal operation, and, although the value per hundredweight is greater than that of fruit or vegetable, approaching that of meat, the majority of the factories concerned are single-storey buildings, although some such as the F. E. Booth Co.'s factory, and that of E. B. Gross Co., at Monterey, are not.

A compromise is achieved in the majority of condensed milk factories, where the evaporating plant necessitates a certain minimum height of the roof and opportunity is thus provided for utilising economically an almost compulsory amount of cubic capacity that would otherwise be wasted. Although many factories operate on a seasonal basis, others operate all the year round, and the multi-storey construction is to some extent justified on this ground as well as on that of the value of the product. The raw milk is pumped to holding tanks and separators on the first floor to feed to the evaporators by gravity. The cans are also fed from this storey and sometimes the finished product is elevated to it for storage, whence it is cheaply delivered by gravity for dispatch by road and rail.

It is in the meat factory where the most carefully articulated multi-storey gravity flow will be found. Lawson Johnston in fact dismisses the single floor meat works very shortly[3] and considers only the multi-floor type. On the top storey the cattle are slaughtered and the carcases are transferred to the refrigeration chambers by overhead rails. From

FIG. 2

CONVEYOR SYSTEM BETWEEN NO. 1 STORE AND NOS. 2 AND 3 AT THE LADY DANE CANNERY.
THE SYSTEM CAN BE SEEN LINKING NO. 1 AND NO. 2

Courtesy of Burt, Boulton & Haywood Ltd., and " Food "

the slaughter floor, there are chutes to the lower floors, whereby offals, hides, and by-products, may be sent to the appropriate departments. On this floor is also situated the can-making department.   On the next floor will be found the cooking and can-filling department.   Below this are the retorts and cooling equipment and, on the ground floor, the label-ing, packing and warehousing facilities.   Although he says that several of the River Plate *frigorificos* are brick-built, the most up-to-date are of reinforced concrete construction.   The internal walls of departments where meat and edible offals are handled, are tiled with glazed brick to a height of 5 or 6 feet from the floor.

Site Value

Another factor influencing design as a single- or multi-storey factory, besides the need for gravitational flow, is obviously the site value.   It will be found that most, if not all, fruit, vegetable and milk canneries are in rural districts where land is comparatively cheap.   All are, so to speak, field crops that will not bear heavy transport charges.   Fish and meat canneries on the other hand are frequently in dockland areas, where ground is often at a considerable premium.   And for that reason alone multi-storey design becomes imperative.

Whether, as time goes on, development in refrigerating and gas storage facilities will permit their economical installation as accessory equipment to the fruit and vegetable cannery, it is obvious that they would revolu-tionise not only the economics of this branch of industry but would lead to the erection of a different cannery building, where multi-storey design would become as general as it is in meat canning.   With the co-ordination of refrigerator transport, especially of the solid carbon dioxide type, which is now successfully applied to the transport of fresh fruit, canneries might be sited at coastal centres.   For the present such development is ruled out on account of cost.   The arguments against refrigerated storage of soft fruits prior to canning have been analysed by Rendle.[16]   Soft fruit is available only for some six to eight weeks : even if cold storage extended it to an extreme limit of say, thirteen weeks, the overhead costs of a comparatively expensive equipment for twelve months must be carried on a quarter of the year.   The possibility of utilising the cold storage facilities during the remaining nine months would be the deciding factor. Joslyn[4] advocates the storage of canned fruit and fruit juice in refrigerated chambers at 32° F.   Were this to become a practicable routine, then it might also be possible to store the fresh fruit, as is now done on fruit farms where facilities for refrigerated gas storage have been provided.

The foregoing summary of the characteristics of the various types of cannery should give some idea of the economic conditions that apply to such factories and the way they are generally handled.   The food chemist is increasingly becoming a chemical engineer, if not in academic qualification, certainly by reason of the problems he has to solve.

Fortunately his duties do not involve the engineering details required for the erection of the fabric of a factory.

Siting

There are certain guiding principles in factory siting that may be usefully enumerated. An excellent summary has been given by Lewis[5] and there is the paper by Stitt already referred to.

The factory site must be considered in the light of the nature of the process, of the product, and in conjunction with the conditions in which the raw materials are delivered and the route by which the finished product reaches the market. In fruit, vegetable and milk canning the raw materials usually arrive by road transport, because rapid transit between orchard and factory is essential owing to the perishability of the raw material. Therefore the site must be chosen at as convenient a road junction as possible. They are usually dispatched by rail and therefore railway facilities are essential. In some instances inland water transport has its advantages. In fish canning, water transport is obviously an important factor. It will be found that the great meat canneries of the world, connected as they are with refrigerated meat undertakings, are sited upon important waterways, usually where there are facilities for ocean transport. The raw materials, livestock, are delivered by rail. In fact the provision of such transport was the *raison d'être* of the Argentine railway system. In a map by Lawson Johnston[6] the manner in which the system serves the coast is very clearly shown. All lines lead to the coastal cannery. This map also brings out clearly the need for siting where transport facilities permit of raw material and finished product being handled in adequate bulk to keep the factory working at capacity.

An essential raw material of the cannery must be provided on the site. That is water. The supply must be independent of the season, it must be available when wanted and in generous measure. All canneries use large quantities and it must be obtained cheaply. Its preparation for the cannery is most important and is dealt with in a later chapter.

Facilities for the disposal of waste are likewise essential, even though the meat packer has been said " to utilise everything except the squeak." The subject of cannery waste is important and is also dealt with in a later chapter. Full particulars should be obtained beforehand of all health authorities' regulations and nuisance laws, both national and local, as well as those of any other bodies likely to affect operating methods. They should be most carefully considered before designing the factory and estimating costs.
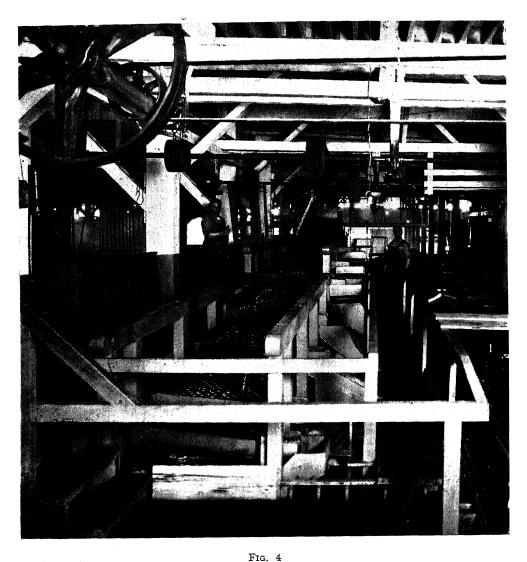
Auxiliary Equipment

The chemist's duties, however, not infrequently involve the purchase of equipment and its economic siting in the factory. Here a knowledge

FIG. 3

THE INCLINED CONVEYOR TAKING THE FILLED CASES TO RAIL WAGON AND, IN CENTRE, THE CENTRAL
CONVEYOR IN NO. 1 STORE

Courtesy of Burt, Boulton & Haywood, Ltd., and " Food "

FIG. 4
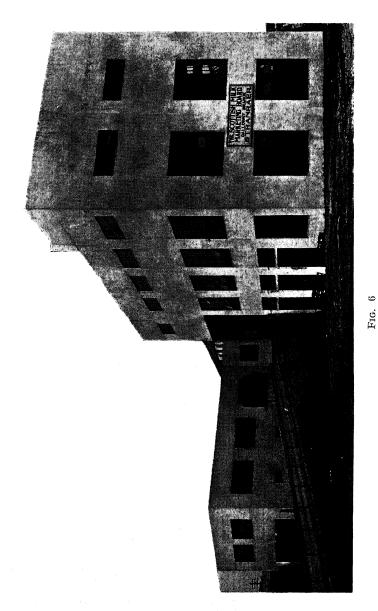
SAN FRANCISCO PLANT OF CALIFORNIA CANNERIES CO. HALVED PEACHES IN COURSE OF GRADING
THROUGH PERFORATED COPPER TRAYS. IT ALSO SHOWS THE FALSE FLOORING IN A SINGLE STORY
CANNERY

Courtesy of " Food."

FIG. 5

SCENE IN THE HAYWARD, CALIFORNIA, PLANT OF THE CALIFORNIA CONSERVING CO., SHOWING THE INGENIOUS FALSE FLOORING IN A 14-ACRE FACTORY

Courtsey of "Food"

Fig. 6

STRANRAER FACTORY OF SCOTTISH MILK MARKETING BOARD, SHOWING THE THREE STOREY CONSTRUCTION

Courtesy of Scottish Milk Marketing Board and " Food ";

of the plant available on the market for operations, is essential. The only way to win this is by careful perusal of the technical journals and by maintaining close touch with the makers so that their latest literature is always at hand. The majority of executives, in fact, find it worth while to maintain a complete file of such literature and keep it up-to-date : there is no other way of keeping oneself informed. Food plant is being improved at such a pace that " new " model succeeds " de-luxe " model, and " improved " model as rapidly as in motoring circles.

The siting of the plant within the factory is a matter of common sense and experience of the operating capacity of each item. Although machines must be placed so that gravitational movement is utilised to the full and the distance between operations is a minimum, thus saving labour, space must be allowed for cleaning and for access for repair and maintenance. But more than this, items of machinery must be placed in such juxtaposition that each is working to capacity, giving a steady flow in time with the total productive capacity of the whole factory. To take an extreme example, it is no use having two labelling machines of a capacity of 7,000 cans per hour at one end of the canning lines if there are not enough fillers or seamers with an output of 120 to 150 cans per minute to feed them. The converse is not so serious since completed cans may be, and usually are, held for a time before labelling.

It is usual to lay out the plant to give what is known as " straight line " operation. That is to say, the raw foodstuff flows straight through the factory in a straight line until the cooled cans leave for the warehouse. The cans, lids, syrup or other additions are fed to the line at appropriate points. Hence a cannery is estimated on the number of " lines " it possesses, and its capacity can be judged by this number, coupled with the speed of each line.

Food Preparation

In view of the importance of the proper preparation of every kind of food before it is ready for the can, attention must be paid to the machinery in use for this purpose. The subject is a vast one but we will deal with it briefly and describe the equipment from the point of view of general principles, leaving it to the reader to find out for himself the merits of individual machines from their makers, who are usually only too glad to supply him with operating details of new units. The plant ranges from the simplest of washing tanks for vegetables to the complex chemical engineering of the milk evaporator.

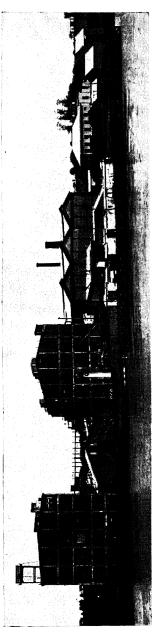American practice, as might be expected in view of the age and scale of the American industry, has formed the foundation upon which this country has based its methods, and American machinery may be observed in operation in the majority of British factories. This is true of all branches of canning, meat, milk, fish as well as fruit. With meat, of course, there is discernible an unmistakable Danish influence, and in

milk, both a Danish and a Swiss.   But at the same time may be observed
the inevitable operation of the national tendency to adapt and acclimatise.
This is perhaps particularly noticeable in fruit canning where British
makers have not been slow to develop competitive equipment.   And
here the Import Duties of 1931 upon special machinery have not been
without their influence.

On the other hand, British canneries cannot vie in size with those of
California or the Argentine.   It is reported that in the Sacramento cannery
of Libby, McNeill and Libby, 17,000 cases of peaches have been packed
in a single day.[7] The average British fruit canning line, at the height of
the season, may be expected to handle somewhere in the neighbourhood
of 4,000 cans per hour.

All types of tanks and machinery are employed for washing fruit and
vegetables.   In some the raw material is carried through a flow of water
on a belt, in others it falls from one sieve to another under a spray of
water, in others fruit and water are agitated by a strong air blast.   The
object in all instances is to free the food from extraneous dirt.

Vegetables.   In Great Britain particular attention has been paid to the
development of plant for the handling of peas. This is as it should be, since
no other single foodstuff, except milk, is canned in this country in such
quantity at the present time. Even in 1934 it headed the list. Therefore
special attention to the pea may not be out of place. Usually the pea is de-
livered to the cannery as mown in the field complete with pod and vine.
In some instances the complete plants are elevated into a viner, in which
they pass longitudinally between two concentric perforated cylinders re-
volving in the same direction. These are fitted with blades whereby the
hulls are split[8] and the peas fall through the perforations in the outer cylin-
der on to an inclined canvas belt down which they roll, any piece of hull or
vine accompanying them being carried on by the belt. The major
proportion of vines, or as they are termed after threshing, the " bines,"
and hulls pass through the cylinder on to another conveyor and are taken
to dumps or to lorries for conveyance back to the pea farm for manure
or sheepfeed. In other instances the threshing is effected by rubber
riddling screens, the result being very similar in nature but more efficient
in operation. From the viner the peas may be passed through a vibrating
sieve to ensure complete removal of particles of vine and shell. For pea
canning on a small scale, plant is available to handle roughly shelled
peas. They are shovelled into a hopper equipped with intermittent
opposed inclined baffles. During the fall down the tortuous baffled
path, the crudely shelled peas meet with a draught of air from a fan which
removes lighter impurities, pieces of shell, etc., while the peas and heavier
particles fall on to an inclined travelling belt. The good peas, as in the
plant already described, roll down the belt whilst the unwanted fragments
are carried upwards. Both methods entirely eliminate the old-fashioned
hand picking.

FIG. 7

SMITHFIELD AND ARGENTINE MEAT CO.'S PLANT AT ZARATE, RIVER PLATE, SHOWING, ON [LEFT, THE EXTRACT PLANT ; CENTRE, THE CANNING PLANT ; AND RIGHT, THE FRIGORIFICO. THE SOLIDITY AND EXTENT OF THE BUILDINGS ARE OBVIOUS

Courtesy of H. G. Lawson Johnston, Esq., and " Food "

[*Facing page* 14

Fig. 8

THE FEEDING END OF TWO PEA VINERS AT THE LADY DANE CANNERY, FAVASHAM

Courtesy of Burt', Boulton & Haywood, Ltd., and " Food "

Grading equipment for peas has also been developed to a considerable degree of elaboration and most canners market three sizes, large, medium, and *petit pois*, giving the grades various names. From the viner the peas may pass to weighing machines and thence by bucket elevator or other means to the washers. Washing is usually necessary, in spite of the elaboration of the viner and other cleaners, to remove small stones, other accidental debris and mucilaginous matter. Most of the last however is eliminated in the grader which is usually a washer as well. In some graders the peas are fed in at one end and travel down an inclined perforated cylinder through which they drop, according to size, into hoppers below. In one grader the peas are passed in series through three revolving perforated cylinders. Each is fitted with a water distribution pipe for thorough washing. The perforations being of different diameter in each cylinder the peas are graded and leave the machine through three different discharge pipes. They fall into appropriate tanks ready for conveying to the blanchers.

It is customary to blanch peas, as it is also to blanch cherries and asparagus in order, paradoxically, to ensure an even and uniform colour when canned. Furthermore, the blanching has the effect of partially shrinking the outer pellicule and thus ensuring a firmness in the finished fruit. For blanching they are immersed for a suitable time, varying, according to the fruit or vegetable and the batch being treated, from two to sixteen minutes in boiling water. Blanching has two other functions : softening and the removal of the outer mucous coating. Over-blanching is more harmful than under-blanching as it causes swelling of the starch and cracking of the peas. The cracks permit the escape of starch and give a cloudy liquor. In modern blanchers the peas are led by means of a spiral conveyor through a drum of boiling water, at a suitably variable speed. The speed may be varied by an externally controlled variable speed gear. The temperature may vary from 185° F. to 212° F. From the blancher the peas usually pass to a cooler, through which again their passage is suitably regulated. The machine is usually fitted with cleaning devices such as water sprayers. Other machines cool and wash by spraying with cold water whilst the peas pass along a vibrating or shaking flat sieve.

As with peas, the blanching operation may be made to serve other functions besides a partial bleaching. With asparagus, for example, it serves as a partial pre-cooking. The blancher, in some asparagus canneries, is in the form of a tunnel through which the spears are conveyed, receiving a treatment with live steam on the way. The blanch lasts about seven minutes, and changes the spears from brittle stalks to pliable spears, a condition in which they are much more easily filled into the cans.

Blanching is important with pears to obtain the conventional pale pack, and it has been advised[14] that they be blanched for two minutes in a weak solution of citric acid.

Blanching is also useful in removing entrained gas. It assists the closer packing of fruit and vegetables. This effect should be viewed with a certain amount of circumspection : fruit and vegetables can be packed too tightly, especially when ripe and wet, for the safety and elegance of the final pack and the remarks made in the following chapter should be noted carefully.

In 1934, about 30 canneries operated in California upon asparagus alone on a Government regulated pack of 1,900,000 cases,[9] and in view of these figures it is interesting to note that the majority of the asparagus was hand graded into six sizes not counting the slender spears and the very thick stalks.   The former were discarded and the latter utilised for soup. The female operators are carefully trained to grade accurately.   Machine grading is a recent development and is accomplished by means of feeding the spears through narrow channels over a perforated table.   This is perforated according to the diameter of the desired grades.   During its travel the grass is washed by sprays and falls through the appropriate holes.   Circular knives cut the vegetable to the desired size, and it then passes to washers operating under pressure.   After blanching the asparagus is graded for colour, three grades usually being put up.

In peach canning in California the peaches are halved and pitted. They then go to the " lye peeler," a tank containing weak caustic solution to loosen the skins without damage to the fruit. A study of the lye peeling of various fruits was made long ago by Bitting.[10] He found it most effective to pass the fruit through the successive tanks, having hot water in the first, hot caustic soda of 3 per cent. strength in the middle one and a weaker hot lye of about 1·3 per cent. in the last.   The period of passage through each bath was twenty seconds.   The fruit passes to the rinsing tank through pressure sprays that effectively remove the skins.   Grading for size is effected by gravity through suitably perforated shaking copper sieves, into seven sizes.

Recent developments in the canning of vegetables have been their packing as slices, dice and purée, the last being a favourite for many vegetables in the United States, particularly for tomato, as it is also in Italy. Dicing and slicing are familiar kitchen operations and the obvious equipment needs no description here.   In the making of tomato purée, the tomatoes are inspected and trimmed, washed and pulped.   The pulpers separate the skins and seeds from the pulped fruit and the pulp then flows to holding tanks, which should be glass lined, where it is held for pumping to steam-jacketed kettles for cooking.   After cooking, the pulp is strained through fine sieves.   It is then ready for filling into cans.

Fruit.   Fruits in general should be firm, ripe, of maximum size, and fully coloured on arrival at the factory. If under-ripened it will be found that there is a tendency for the fruit to shrivel and toughen on canning : and that it does not swell out again to its normal shape on processing. Over-ripe fruit, on the other hand, breaks down easily on processing and

FIG. 9

PEA WASHER AND GRADER

Courtesy of Burt, Boulton & Haywood, Ltd., and the " Industrial Chemist "

gives a most unpresentable pack. Further, over-ripe fruit may easily be stale fruit, and this possesses the added danger of being possibly heavily infected with micro-organisms that will have a damaging effect upon the pack.. There is another danger in over-ripe fruit and that is its loss of acidity. Acidity in fruit, as will be discussed in a later chapter, is relied upon to a considerable extent in processing to achieve sterility in the final pack. There are one or two fruits to which these general rules do not apply.

Exceptions are gooseberries, which are green and hard when canned, and blackberries, which should be fully ripe. Evenness of maturity and free-dom from malformation, from spray residues and insect or disease blemishes are important. Attention is usually paid to size, since the modest scale of the British cannery does not permit the packing of a considerable variety of sizes of any one fruit. An average size is the desideratum, although really large sized strawberries and Victoria plums are often appreciated. Under-sized fruit is to be avoided, as the consumer will not knowingly purchase it. A high ratio of stone to flesh in stoned fruit such as plums and cherries is likewise objectionable. In general, attention is paid to colour, shape, firmness and freedom from blemishes and malformation, to flavour, texture and proportion of inedible matter such as stone and pip. Investigations have been steadily prosecuted for many years at the Campden Research Station into the suitability for canning of different varieties of fruit and vegetables, and the monographs and annual reports of that laboratory should be consulted. Work in this direction has also been carried out with a view to standardisation under the National Mark and there are available various leaflets published by the Ministry of Agriculture and Fisheries, the most important being Leaflet No. 20, published in 1935.[17]
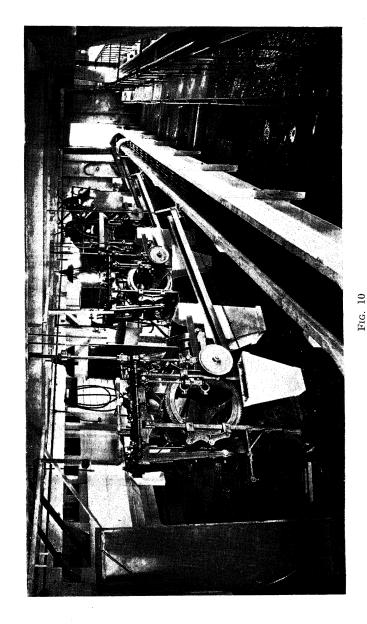
This work has been summarised by Hirst.[18] It has revealed the seasonal and regional variations in the quality of fruits and vegetables used for canning, and the difficulty of precise definition of many of the qualities desiderated. Colour can only be defined in general terms ; as also can texture ; foreign flavours can be more easily detected than quality and " fullness " of flavour. Grading for size, blemishes and defects, weights, syrup densities and total weight of can contents, have been more amenable to delimitation and much progress has been made. Seasonal conditions affect the fluctuations in fruit and vegetable size : each class of fruit has its own type of blemish and the frequency of blemish depends largely on seasonal conditions, but it may be reduced by special care in growing. Standards for weights of fruit and vegetables have been established, and so have syrup strengths.

Since colour is an important sales factor in canned foods, and certain fruits tend to discolour or to colour unevenly, much attention has been paid to this problem. Some, such as cherries and strawberries, need artificial colouring, sometimes after initial blanching. Considerable work

in this direction has been carried out at Campden and the original papers should be consulted. Morris, at the Cambridge Low Temperature Research Station has investigated the prevention of the browning of sliced apples and the expulsion from them of oxygen in the tissues. This is most efficiently achieved by steaming the fresh cut slices, passing them through a brine tank between slicing and steaming. Apples are also canned whole, and of course have to be peeled and cored. These operations may now be effected mechanically on a single machine. The coring knife is first used as an impaler, turning the apple against a stationary knife which removes the peel. The apple is then held stationary whilst the coring knife rotates rapidly. The apple then drops off into a trough of water whence it passes to a brine bath before filling into the can.

All fruit and vegetables have to be examined for quality after the preliminary operations have been carried out. This is done by visual inspection as they travel along a belt to the canning line. It is necessary, in order to detect fruit or vegetables not up to standard because they are broken, badly formed or discoloured. The offenders are picked off by hand and discarded. Female labour is usually employed and speedily becomes highly efficient. The belts should be as long as conveniently possible, well lighted and the rate of travel should be as slow as the daily output will permit. Some canners have found it desirable to instal some device that will rotate the fruit during the travel. A simple method is to arrange for one or two " falls," that will turn the fruit over. Another device, is the " divided belt " system, but this is only suitable for large fruit that is not easily damaged. In this there are three parallel belts and each fruit has to be lifted on to the central one before it proceeds to the canning line.

Fish. Cahalin has given an interesting description of sardine canning at Monterey, on the Californian coast.[11] The fish are discharged from the fishing fleet to floating hoppers, whence the fish is pumped to the cannery through a pipe line by an 8-inch centrifugal pump. Each cannery maintains its own hopper and pipe line. Owing to disputes with the fishermen the canneries now employ automatic scales which print the weight at the cannery in triplicate, one for the fishermen, one for the cannery and the other for the State Fish and Game Commission. The fish are then washed through a scaler, a revolving coarse-mesh drum which, under the influence of a heavy water spray, removes the scales by friction with the sides of the wire drum. All sardine canneries are equipped with cutting and cleaning machines for decapitation and gutting. Some carry the fish to a disc knife revolving at high speed, which cuts through the fish, partially severing the head ; then spiral-shaped knives, with a sweeping motion, remove guts and head. Others cut the head off completely and clean the body cavity with gimlets or brushes. The fish is then cut the proper length for packing. In another type the fish are shaken on to a conveyor and fed to a decapitating machine where they

FIG. 10

"IRON CHINKS" IN A CALIFORNIAN SALMON CANNERY, WITH CHAIN CONVEYOR TO THE INSPECTION TABLES
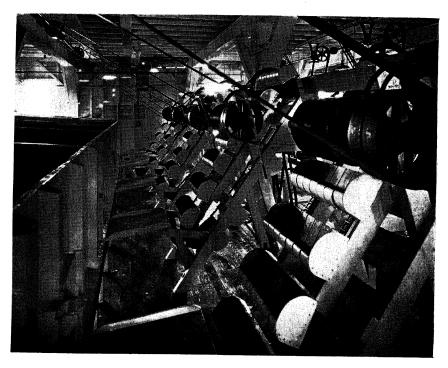
Courtesy of "Food"

FIG. 11

SALMON CUTTING MACHINES. SALMON IS PLACED IN THE TRAYS AND DEVIATED TO THE
KNIVES, WHICH CUT IT TO THE SIZE INDICATED BY THE SLITS IN THE TRAYS. KNIVES
ARE VARIOUSLY SPACED TO CUT THE FISH FOR DIFFERENT SIZED TINS

Courtesy of " Food "

[Facing page 19

are simultaneously cleaned by vacuum. A battery of such machines may have a capacity of 30 tons per hour. The fish are then graded by hand.

It is of course in salmon canning that preparing machinery has been particularly highly developed over a long period of years. In the early days gutting and cleaning were performed by hand. On the Pacific coast of America, according to Cahalin[12] this work was invariably carried out by Chinamen, as they were the only hands with the skill and endurance for the long hours of work at the high speed demanded. Hence the first gutting machine was named the " iron chink," a name which has endured. The following description is taken from the article referred to.

From a conveyor running the length of a battery of " iron chinks " the salmon are placed by hand on the sloping tray of the machine. The first operation removes the head and tail. The fish is then caught on a circular drum and, travelling round this, meets knives and brushes that cut off the fins, split open the belly and clean out the viscera. It is then automatically released and delivered to a conveyor which acts as an inspection belt. It is then washed and any adhering blood or viscera cleaned away. The fish is then cut mechanically to the desired size for canning, and filled into the can by hand, or mechanically. Mechanical filling has developed considerably of recent years, and an innovation, being generally adopted, is mechanically controlled weighing before delivery to the vacuum closing machines.

Milk. Canned milk appears upon the market in several forms, in all of which part of the water has been evaporated and the fats and other constituents concentrated. Evaporation may be applied to the whole milk, or the latter may be separated from the cream beforehand. Furthermore, the separated and evaporated product may be sweetened before canning. Unsweetened full cream and skimmed milks may be sterilised in tins or not. If sterilised, it is usually termed " evaporated " milk. Hence the canned milk products found in commerce include condensed full milk sweetened, condensed full milk unsweetened, skimmed milk sweetened and unsweetened and canned cream, and evaporated milks.

To-day condensed milk has so far established itself that it is regarded as one of the longest keeping of canned foods. The high percentage of sugar in the sweetened product prevents micro-organic spoilage. Unsweetened condensed milk is sterilised at such a high temperature that spoilage is almost unknown. On the other hand these same two conditions impose their penalties. Unless the raw milk is of good composition and hygienic quality the milk cannot be successfully treated to yield a sound foodstuff as well as one possessing the creamy smoothness desiderated by the purchasing public. The coagulating tendency of milk above 100° C. at atmospheric pressure imposes stringent conditions upon the evaporation of its water to yield a condensed product.

The evaporation of milk for canning might almost be regarded as a

branch of chemical engineering in itself and space forbids its being dealt with in more than the briefest outline.

If the undesirable effects of heat coagulation are to be avoided, the raw milk must conform to certain standards. Its heat-resistant qualities depend to a certain extent upon its acidity, which should be below 0·18 per cent. lactic acid or 20 degrees Dornic, upon the fat to solids not fat ratio, which should be, or should be adjusted to be 1 : 2·44. If, on application of the alcohol test, there is visible coagulation, the milk will become curdy during sterilisation. Another test is the phosphate test, coagulation with this indicating heat instability. Of these tests, which are described more fully in a later chapter, the first one and the last two should be given attention, and the results from all three carefully weighed up when dealing with doubtful samples. The fat to solids not fat ratio of 1 : 2·44 should be strictly adhered to if processing troubles are to be avoided and the product is to conform to the Condensed Milk Regulations of 1923.

Every effort should be made to encourage the production of milk of good hygienic quality. The canner's reward will be found in a lower percentage of rejections during warm weather, in less trouble in the condensing operations, and in fewer faults in the packed product.

The milk is received at the factory or condensery in churns or tank wagons. It is then poured into receiving tanks on weighbridges and pumped to holding tanks. Samples are taken at this stage. The chief tests, in addition to those given, are for sediment or visible dirt, bacterial count, and *B. coli*. The reductase test has its devotees, but also its shortcomings.

From the holding tank the milk passes to storage or direct to the evaporating plant. In the latter it first passes to a preheater and thence through a feed tank to the evaporator. The milk goes from the preheater to the evaporator if the unsweetened product is desired, but is sweetened first if the sweetened is to be manufactured. Coarsely granulated sugar is added and dissolved, the amount to be added being calculated from analyses of the raw milk and the finished product. The sucrose content of ordinary condensed milk is 42 per cent. There are a number of both preheaters and evaporators on the market. Their design is a highly skilled engineering problem in view of the narrow temperature range to which the milk may be successfully subjected. The evaporators are therefore all designed to work under a vacuum of some 29 ins. and at a maximum temperature of about 145° F. In the more modern evaporators the milk is subjected to forced circulation by means of an impeller and in this way rapid heat transfer is effected and stagnant spots which might lead to burning of the milk are eliminated. Condensation of the evaporated water is also an important feature of the modern evaporator and considerable attention has been paid to efficient operation. In yet another type of evaporator the milk is continuously evaporated by the " climbing film " method.
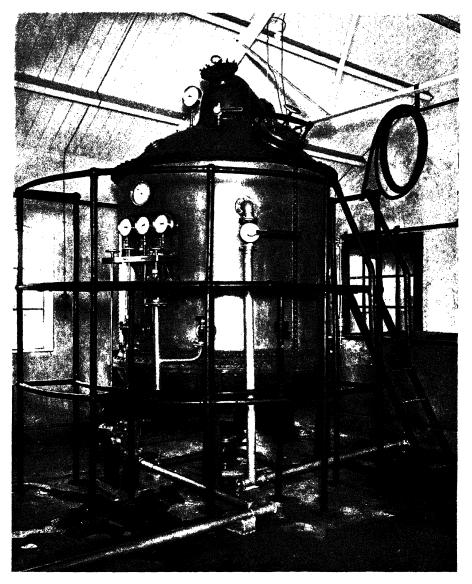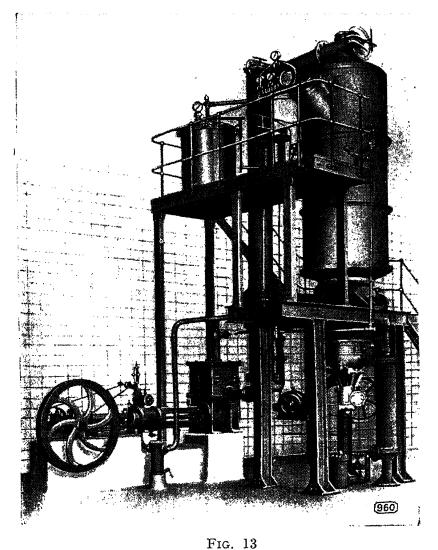
Fig. 12

COIL HEATER TYPE OF VACUUM PAN; SIX FEET DIAMETER; CAPACITY 600-GALLON CHARGE PER HOUR; TINNED COPPER; VACUUM 26 INS.; TEMPERATURE 50° C.

Courtesy of Express Dairy Co., Ltd., and " Food "

FIG. 13

A FORCED CIRCULATION MILK CONDENSING PLANT, THAT
MAY BE USED FOR BATCH OR CONTINUOUS OPERATION

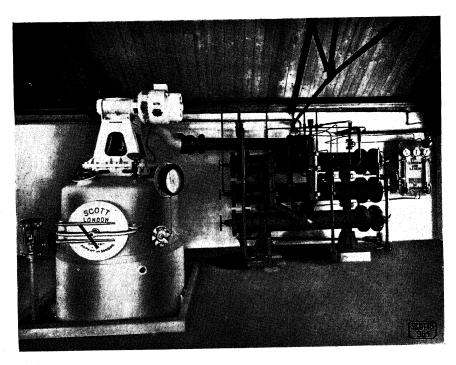*Courtesy of Geo. Scott & Son (London), Ltd.*

FIG. 13A

THE VESSEL ON THE LEFT IS A SCOTT PATENT HIGH VACUUM CONDENSED MILK COOLER.
IN THIS THE CONDENSED MILK IS COOLED TO ATMOSPHERIC TEMPERATURE BY SUBJECT-
ING IT TO A VERY HIGH VACUUM

Courtesy of Geo. Scott & Son (London), Ltd.

FIG. 14

VIEW OF LOWER PART OF CLIMBING FILM EFFECT EVAPORATOR, WITH
BASE PLATE SWUNG FREE FOR CLEANING ; IN BACKGROUND IS THE
FEED TANK TO THE EVAPORATOR

Courtesy of Kestner Evaporator & Engineering Co., Ltd., and " Food "

With the continuously operated evaporator the necessary adjustment of temperature and vacuum is made until the product runs off at the desired composition.   With batch operation it is " struck " or sampled, as the composition approaches the desired stage.   This is usually esti- mated by the Baumé hydrometer and the composition calculated from tables.   The reading on mechanical instruments can, of course, only be trusted when the chemical composition and temperature are properly controlled, hence the need for standardising the fat, solids not fat and sucrose contents.

Batch completion requires particularly careful attention when evapor- ating for unsweetened sterilised milk.   Davies[15] advises the running of a pilot coagulation test on a batch of six tins each containing 6 oz. of milk and added sodium bicarbonate solution equivalent to 0, 1, 2 . . . 5 oz. of bicarbonate per 1,000 lbs. of condensed milk.   The tins are sterilised at 243° F. for 15 minutes, cooled and the viscosity tested. The tin giving the optimum is indicative of the requisite quantity of bicarbonate and this quantity is added to the batch.   Sodium citrate and sodium phosphate are also used to correct the salt balance of evapor- ated milk and thus raise the heat coagulation point.   The range usually covered is from 2 to 10 ozs. per 1,000 lbs.

After evaporation the milk has to be homogenised to ensure a stable dispersion of the fats and casein.   Here again the milk canner has a wide choice of homogenising equipment.   In the more modern plants homo- genisation is succeeded by filtration and then cooling.   Cooling again is an operation needing the greatest care so that the homogenity of the product at this stage may be preserved, otherwise there is a tendency for the milk sugars to crystallise out.   This gives the product an undesirable " sandiness."   There are several methods of achieving it.   According to a description of certain of the factories of the Scottish Milk Marketing Board,[13] the filtered milk is cooled in a large stainless steel tank fitted with a spiral mixer, passed through a heat exchanger, back to the tank and so on until the desired temperature is reached.   The milk then goes to storage or direct through holding tanks to the filling machines.

Although lacking detail the foregoing will give some impression of the equipment to be found in the condensery.   It is obvious that every possible precaution must be taken against contamination, both bacterial and chemical.   All plant must be resistant to chemical attack by the milk and readily cleaned.   Glass, stainless steel, aluminium and similar materials of construction are a *sine qua non*.   Glass-lined holding tanks are now the general rule, and stainless steel is replacing tinned copper wherever possible, although this type of construction will be found in many evaporators.   Pipes and pumping demand special attention.   All piping should be in straight sections with screwed plugs at the elbows to permit easy access for cleaning.   The sections should be short and screwed together so that everything can be completely dismantled.

For similar reasons pumps of the centrifugal type are to be preferred : they possess few moving parts and the minimum of pockets where milk might collect.   Cooling may be effected by cold water or cold brine, and where the latter is used the materials of construction demand careful selection.

Meat.   The canning of fish and meat present their own peculiar problems, for there is no naturally occurring substance which lends itself more readily to the ravages of bacterial action.   Successful handling calls for a specialised technical knowledge, the possession of which is not perhaps needed to a like extent in any other branch of the canning industry.

With meat, if success is to be achieved, the treatment of the raw material really commences with the quality of the live animal.   Poor quality meat will not turn out a high quality canned article, and neither will good quality meat, unless it receives suitable treatment throughout the processes.

Too much stress cannot be laid upon the handling of the carcase immediately after slaughter.   It is an established fact that the greater the bacterial contamination of a substance, the more difficult it becomes to render that substance sterile during the actual canning operation. Every reasonable precaution should therefore be taken to guard against avoidable introduction of putrefactive and other organisms.   The intestines of all animals commonly used for human food swarm with bacteria, which may even be present in the stomach if the animal is killed too soon after feeding, or in rare cases, where it is suffering from disease.   Careful removal of the viscera by a skilled operator will minimise the danger of the edible part of the carcase becoming contaminated with the contents of the bowels, and veterinary inspection is designed to guard against the use of the flesh of diseased animals in the manufacture of food.   However, it is, of course, impossible to introduce into the slaughter house the surgical technique of the operating theatre, and consequently even although the flesh of an animal may be sterile at the time of slaughter, some bacterial contamination is inevitable, and must be dealt with.

A rapid reduction of temperature of the flesh is the most effective practical method of checking bacterial activity, and therefore in the abattoir attached to a canning factory the carcase should be placed in a chill room as quickly as possible after slaughter.   The temperature of the chill room should be as near freezing point as possible, but should not reach the freezing point of meat, otherwise loss of flavour will follow due to " drip " on thawing out ; further, the meat in a frozen condition cannot be handled by the butcher.   If the meat is to be held over a prolonged period it must be frozen and kept frozen.   It is much better to handle the meat as quickly as possible after it has become uniformly chilled, than to deal with meat which has been frozen and subsequently thawed.

The preliminary operations in the meat cannery may involve, in addition to slaughtering and butchering, cooling, curing, and blanching.

The object to be aimed at is to keep the number of organisms at the lowest possible limit right up to the time that the material is in the can ready to be subjected to the process of sterilisation, and therefore precautions are needed at all stages.   After chilling, the flesh has to be removed from the bones, and to be sorted into the various parts for every particular variety of finished article.   Only a sufficient number of carcases should be taken out of chill to cover immediate requirements, and if those engaged in this stage of the preparation of the flesh work more quickly than those engaged in the subsequent operations, then the meat should invariably be returned to a chill room to await further treatment.   The temperature of the room in which bones are removed should be kept as low as is consistent with the health and comfort of the operators.   In the most modern factories temperature and humidity are controlled by air conditioning.   Scrupulous cleanliness is absolutely essential, and all utensils must be sterilised as often as possible, at least twice per day.

The meat may be canned without the addition of other ingredients, or it may be mixed with spices, fillers, etc., to produce such articles as galantines.   In some cases, for example, corned beef, canned bacon, etc., cured meat will be used, and where possible it is preferable to cure the meat in relatively large pieces, with subsequent slicing after cure.   It should be remembered that curing pickles frequently carry a very heavy bacterial flora, which remains inoperative because of the high concentration of the salt in the pickle.   When the inhibiting action of the salt is removed, that is, when the meat is taken from the curing vats, the bacteria quickly become active, and it is a good plan to subject such meat to a thorough spraying and washing with clean water, and then to use the utmost reasonable speed to get the meat into the cans and cooked.

Corned Beef.   After slaughter and dressing the carcases are chilled to a temperature of about 42° F., and from the chill room they pass to the boning department where the meat is completely freed from bones.   The meat is then cut in a special machine which produces pieces about 12 inches long and an inch thick and approximately an inch in width.   The machine feeds the meat into a cooking pan of about one ton capacity, fitted with a perforated bottom, under which lies the steam coil.   Water is added at the rate of one pound for every pound of meat, and the mixture raised to boiling point, which temperature is maintained for 30 minutes. At the end of this period the liquor is either pumped off or gravitated to the meat extract plant, where it is concentrated to produce meat extract.   The meat is allowed to drain and cool somewhat, and then pickled in hot pickle containing approximately 0·06 per cent. sodium or potassium nitrite, and 8 to 10 per cent. of salt.   The temperature of the pickle is maintained at 168° to 170° F., and the meat steeped in it for a period of 4½ to 5 hours.   The pickle is then pumped away from the meat, passed

through a filter press, cooled and its strength corrected, when it is ready for the next batch of meat. The meat is allowed to drain and then passed to the dressing tables, where any sinew is removed and trimming carried out. From this point it passes on conveyors to the can stuffing machine, which automatically fills the cans with the correct weight. A sufficient quantity of " soup stock " is then added. The cap is then soldered upon the can, and after testing for leaks the can passes to the vacuum exhausting plant, and the vent-hole completely closed while the can is under vacuum.

Flooring

In the single-storey building, obtaining in fruit and vegetable canning, concrete floors are cheaply laid and will be found general. Where there is much fatty fluid to handle, then a fat-resistant floor is essential, and the modern milk canning factory is built with such floors at all levels. In any cannery the quantity of liquid handled necessitates careful attention to drainage. All floors must have a fall towards the drain, sufficient to ensure that fluid waste and wash water run off readily. One eighth of an inch per foot is the minimum, but should not be exceeded too greatly or the floor will be a difficult one to work on. There are two chief systems. One is to provide each appropriate floor area with its cast-iron drain box complete with strainer and trap, the floor being sloped down to it. The other is to slope the floor to a gutter, covered with a grid. This in turn slopes down to a drain, frequently outside the building, provided with strainer and trap. Drain pipes and gutters should be large enough to handle the normal load with something to spare. All pipes from a cannery floor should be four or five inches in diameter and the jointing should be easily dismantled for cleaning. The pipe line fall should not be less than one inch in five feet. The disposal of cannery waste includes that of the drainage and is dealt with in a later chapter.

Air Conditioning

Reference has been made above to the need for properly conditioned air in the canned meat factory. Although of course it would be working under ideally hygienic conditions were it adopted in all canned food factories, it is particularly essential with meat, owing to the readiness with which meat is attacked by bacteria and the length of time the meat is exposed in the process of cutting up. Considerations of cost would prevent such elaborate precautions being taken in fruit and vegetable canning, even were the results proved to justify such outlay. The acidity of the fruit, the fact that most of it is canned in its natural skin, and that much of it is canned in syrup, are conditions that must lead one to doubt whether air conditioning is necessary. With milk it must be remembered
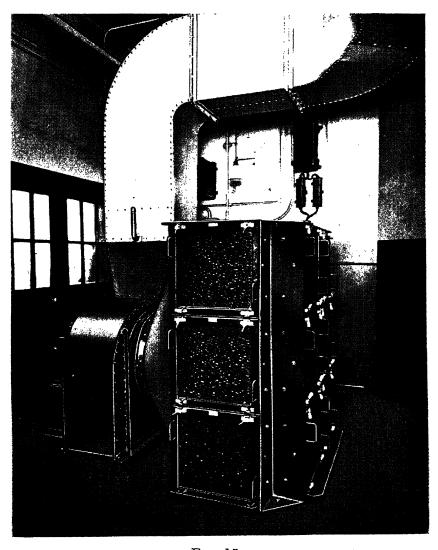
Fig. 15

A VISCO DUPLEX AIR FILTER, SHOWING FILTER FRAMES AND FAN

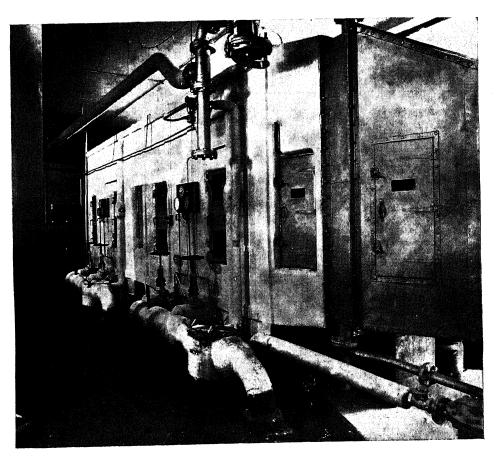*Courtesy of Visco Engineering Co., Ltd., and " Food "*

FIG. 16

.A " CARRIER " AIR CONDITIONING INSTALLATION IN THE COATING DEPARTMENT OF THE WEMBLEY
FACTORY OF MESSRS. WRIGLEY PRODUCTS LTD.

Courtesy of Wrigley Products Ltd., and " Food "

that once the raw material reaches the factory it enters into a circuit closed to the air except for the fractional time it is filling into the cans. When canning fish and meat, however, the atmosphere within the factory must be carefully looked after.

Improvement of Quality

Careful investigation has proved that, by manufacturing most articles of food in air conditioned to the right degree of temperature and humidity, a very marked improvement is effected in the keeping quality and appearance of the finished product. Of course, different kinds of food need different atmospheric conditions, and in some cases air filtration may be all that is necessary. In others, temperature and the percentage of relative humidity play an important part, but it may be safely asserted that in all circumstances filtration is highly desirable.

In order that a system of air conditioning may be fully efficient for premises where food manufacture is conducted, the plant must ensure accurate and uniform control of (a) air cleaning ; (b) temperature ; (c) humidity ; and (d) volume and distribution. The climatic conditions in the United Kingdom are subject to such rapid changes that the conditioning plant must be of automatic design and must control its operations in such a manner that it will at once adjust itself to the changed state of the raw material (air) it is expected to handle. Obviously, under such conditions any other than automatic control would not be practicable.

In those departments of a food factory where air humidity and variations in temperature are either not important or do not lend themselves to control, filtration may be resorted to.

Air filtration is usually carried out by passing the whole of the air supply for the department through a filtering device by means of a suction fan, and if possible the filter should deal with air direct from outside the premises. The air is distributed to various points within by means of ducts, fitted with movable slots. The filter proper consists of a series of deep metal frames fitted with baffling devices coated with a viscous substance, such as heavy mineral oil, which preferably contains a germicide, such as copper oleate. The baffling devices are so arranged that the incoming air must impinge upon two or more of them and the dust, mould spores and most of the micro-organisms adhere to the solution with which the baffles are coated. The frames containing the baffles are built together into what may be described as a battery, and every frame can be easily detached and removed for cleaning purposes. In practice, spare baffle frames or filtering units are provided so that cleaning may be carried on without interfering with the continual operation of the filter ; when a frame is removed a spare is put in its place. A satisfactory filter, if properly cared for, should show an efficiency of practically 100 per cent. for the removal of dust and mould spores, and not less than 95 per cent.

for the removal of bacteria.   A filter of this kind is of great service where rapid spoilage of an article is likely to be caused by mould growth.

Washing and De-humidification

Where humidity and temperature are of importance, it is usual to dispense with the preliminary filtration of the air by the means described and to rely upon a washing process, which is a necessary part of the conditioning.   It is seldom possible to obtain the desired air conditions without de-humidification of the " raw " air.   The excess of moisture not required is removed by cooling the air to a predetermined temperature below its initial dew-point temperature.   By re-heating, the desired amount of relative humidity is obtained.   In practice it is usual to de-humidify and wash the air in one operation.   The arrangement of the washing device causes the incoming air to meet atomised sprays of water moving at a high velocity.   This cleans and cools the air in one operation, causing condensation of the surplus water (which, of course, is brought about by the drop in temperature), and the air leaves this portion of the plant in a cold, saturated condition.   It is then passed over a heating coil and its temperature adjusted to the desired degree.   The efficiency of the plant will, to a great extent, depend upon the temperature of the spray water, and it is nearly always necessary to employ refrigeration. Where this is so, the water can be re-circulated many times after its temperature has been reduced to the right degree.   In an automatic plant, in order that a constant air temperature and relative humidity may be maintained, a thermostat is fixed at the discharge of the air washer, and arranged in such a position that it is not exposed to the free moisture from the washer, nor radiant heat from the main heater.   It will therefore be subject to the dew-point temperature of the passing air. Any alteration in temperature is at once transmitted by the regulator to the valves on the plant and they open or close according to requirements.

In arriving at a decision as to the optimum air conditions in which an article of food is to be handled, it is advisable to consider what subsequent temperature the product is likely to meet.   If it is to be dispatched as soon as possible after manufacture and has to make a journey in a closed and heated van, it will obviously be undesirable to pack it at too low a temperature because, if this is done, trouble is almost certain to arise through the condensation of moisture from the surrounding air in the vehicle, and the article with its wrapping may arrive at its destination in a saturated and spoilt condition.

Observation over a prolonged period has shown that the output and health of individual workers undergoes a marked improvement in those departments where filtered and conditioned air is used.   Where there is a careful control of atmospheric humidity, the feeling of lassitude, invariably experienced upon a " close " day, soon passes away when de-humidi-
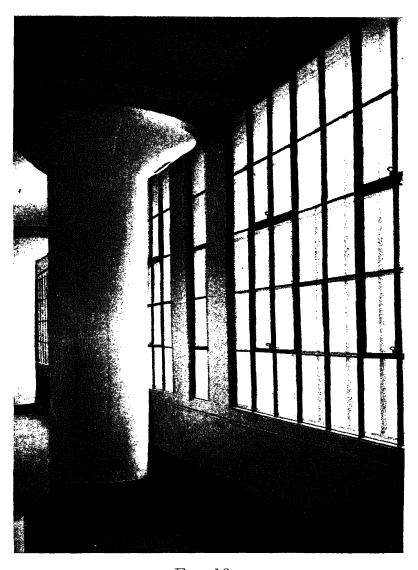
FIG. 16A

DOUBLE WINDOWS IN ONE OF THE AIR CONDITIONED
ROOMS OF THE WRIGLEY FACTORY

Courtesy of Wrigley Products, Ltd., and " Food "

fied air is breathed, and the removal of micro-organisms from the air by filtration helps to combat the spread of infectious diseases.

There are several air-conditioning systems upon the market to-day and they are not only exceedingly efficient but extraordinarily adaptable. The whole factory may be run as one unit or selected rooms or floors may be run as separate units. The essential central equipment is, of course, the refrigerating plant. The air washing, cooling and heating may be done in one plant, or separate plants, for special duty, may be located at convenient points in the building, the brine being conveyed thereto. It is clear that no building can be perfectly hermetically sealed and some of the conditioned air must be inevitably lost to the outside atmosphere. But for economical working as much as possible of the conditioned air is withdrawn and recirculated *via* the conditioning plant, and make-up air drawn into the system in the most economical quantity. In some factories, the ingress of dirt and other suspended matter is completely combated by keeping the internal conditioned atmosphere at a slight pressure. Dust is thereby blown outwards and never into the rooms. One of the best examples in the United Kingdom is the North Wembley factory of Messrs. Wrigley Products, Ltd. The product is extremely sensitive to moisture and readily soils : the atmosphere is therefore kept at 70° F. dry bulb and 60° F. wet bulb. The various rooms are sealed with double windows and possess their own conditioning plant, each having its appropriate atmosphere. All doors open inwards and the air is under a pressure slightly above atmospheric.

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CHAPTER III

CANNING

THE outline of the process of canning given in the Preface needs elaboration, even if only to make the description complete. In this chapter the whole process is described so far as concerns the operations involved in canning the food. The preparation of the food for canning has already been described and in later chapters are given methods for the chemical examination of raw materials and the chemical and bacteriological examination of the finished products.

The operations involved include the making of the can, its washing, filling, exhaustion of air, closing, sterilising, cooling, storing and labelling. The filling, except with milk and other fluids, like fruit juices, involves two separate operations and these may be carried out simultaneously or sequentially. One is the filling with the solid food, and the second is the addition of fluid to the solid. This may be syrup to fruit, brine to peas, gelatine or soup to meat, or sauce to meat or fish, or oil to fish. Practically every operation may be carried out in various ways. Exhausting may be carried out by boiling water, steam or vacuum. It may be carried out upon the open can, the can with its lid loosely resting on it, loosely clipped on, or soldered on. Sterilising, commonly known as " retorting " or " processing," may be a continuous or a batch operation. Cooling may be by plunging in water or by squirting jets of water upon the hot can. There are nearly as many ways of canning as of constructing tribal lays and any one of them may be right for the particular food being canned. There are several causes why they may all go wrong and in the last section of the chapter will be found a few hints upon the matter.

The Can

The general rule is for fruit, fruit juices, vegetables, milk and soups to be canned in cylindrical tinplate cans. Certain meats, fish, and some packs of asparagus provide the exception. It is claimed that packing asparagus in rectangular tins prevents damage of the spears : upon cooling the vacuum produced in the can draws in the four sides slightly and holds the spears so that they cannot move about and rub off the side leaves and buds : packed in cylindrical tins it is said that there is considerable likelihood of the spears moving about. Hams, gammons, briskets, and chicken and ham roll are packed in specially shaped cans;

hams and gammons in those most suitable to their natural shape, briskets and chicken and ham roll in the conventional shape that has now become standardised. The same is true of corned beef, which still appears on the market in the original tapered rectangular tin. The flat shallow rectangular sardine tin is well known, as also is the shallow oval of the herring in tomato sauce. The cylindrical can has enormous advantages in factory operation. It rolls naturally and so can be moved by its own weight : the circular bottoms and lids are easily fixed on at speed, and labelling can be an exceedingly high speed operation.

" Sanitary " or " Solderless " and " Hole and Cap "

These are the two kinds of can. The former is in more general use. Its name is derived from the fact that it is not soldered on the inside joints, and therefore no solder or flux can come into contact with the foodstuff. The vast majority of foods is packed in this way. The food is filled into the lidless can, and the lid seamed on. The sanitary can is usually of cylindrical shape, made in three pieces from flat sheet. There are exceptions such as the shallow ovals for some types of fish, which are " drawn " out of the single sheet.

For some classes of canning, the older " hole and cap " has definite advantages. This is particularly true of some meats. The decomposition of meat protein by heat liberates a quantity of sulphuretted hydrogen and this may cause discoloration of the inside of the can, or even of the meat itself. Kidneys and liver appear to suffer more readily from this way of decomposition than other types of meat, and therefore many canners always use this class of can for them. The material is placed in the lidless can and the lid soldered on, a small vent hole in it being left open. The can is retorted for practically the whole of the necessary period, then removed from the retort, and while still hot the hole is soldered up ; the can is then returned to the retort for the remainder of its sterilising period. By this means much of the sulphuretted hydrogen is allowed to escape and discoloration is reduced to a minimum. Most non-cylindrical cans are of this type, and they have a lapped joint on the side and double seaming on the bottom, with all seams soldered. The top is also double seamed and finally soldered. . Some Continental cans are ribbed longitudinally round the sides to acquire increased strength.

Since the sanitary can is the general rule, and the only difference in processing between the two types lies in the removal during retorting, we shall not again refer to the hole and cap variety. It must be borne in mind however that this difference adds to the advantages of the sanitary can, being another reason why it lends itself to the modern development of the automatic can line.
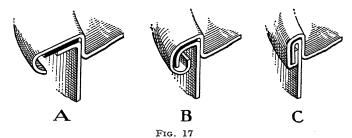
In the cannery of sufficient turnover, i.e., the majority, the can is manufactured on the premises. The sheets of tinplate are cut to rect-

angular shapes for the body blanks on machines known as slitters. These are then notched at the corners, the edges of the ends of the blank are hooked : the blanks are then bent to cylindrical shape, the hooks engaged and flattened on a mandrel to lock them. The locked seam, the side seam of the can, is then soldered. All these operations are carried out so rapidly as to be performed almost simultaneously. The cut blanks are fed, in the machine, to the notching position, thence to the hook-forming mechanism, and then the flux is applied to the hooks. The fluxed hooked blank is wrapped round the mandrel, which then expands and engages the hooks and bears up against a flattening hammer. The body is then pushed on to a second mandrel and travels along this horizontally with the side seam underneath. More flux is applied and then solder by means of a roller. Excess solder is buffed off and an air blast cools the joint. The can body is then transferred to a flanging machine where both ends are flanged. The body is then ready for the bottom and the lid. These ends are stamped out by special machines capable of taking the whole sheet or strips wide enough for a single or a double row of ends. For economy's sake, the machines cut the discs from the sheet in a " staggered " pattern, this reduces the waste of tin sheet considerably : such machines are known as " scroll shear " machines. The discs then pass to the stamping machine where they are impressed with the necessary corrugations. Then in another machine, or an attachment to the same machine, a thin layer of sealing fluid is run into the outer flange or curled rim of the end. The volatile solvent of the rubber composition is evaporated off in an oven, and the ends are ready for double seaming on to the can body. At this stage the bottom only is affixed, the lid being put on at a later stage after the can is filled with foodstuff. The operation of double seaming is the same for both and may therefore be described now.

Double-seaming machines differ in detail but not in principle. The recessed can end is fed from the hopper to fit closely round the base of a vertical chuck and the body is brought up to it on a holding-up plate. The flange on the can body then fits loosely into the outer flange or curled rim of the end, and a pair of first operation rollers revolve planet wise against the flanges and curl them together. This is the operation of the first turret, as it is called. The can is then transferred to the second turret where rollers with a shallower recess flatten the seam tight. The seaming rollers rotate, but the can is held stationary so that the contents of full cans shall not be spilt. From the second turret the can is discharged. These operations have the effect of causing the body edge to be enclosed in a cushion of rubber inside the double seam, making an airtight joint. The bodies with the bottoms attached are then tested for leaky joints by filling them with compressed air in an automatic machine, and those that leak are automatically rejected. The testing heads are mounted on a large wheel, rotated vertically, and near the

end of a complete revolution each sound can is automatically released to go to store or the can line.

When it is considered that output does not warrant the installation of complete can-making machinery, it is usual to purchase the completed can body, bottoms and lids.   As double-seaming machines for the lids are an essential part of the can line, they, or a spare machine, can serve for affixing the bottoms.   For convenience in transport the can bodies are purchased pressed flat and opened out by a special machine known as a " flexer " which rolls them to perfect cylindrical shape.   Such a machine has also its uses even when cans are manufactured on the premises, as it ensures well-shaped cans and eliminates " flats " : these, because of their bad shape, are a frequent cause of blockage on the canning line.

Can Sizes

The shapes and sizes of cans would appear to be legion, and every manufacturer would seem to have entered into a mad competition to add yet another novelty of so-called distinction to the market.   Fortunately the competition would seem to have passed its zenith and a more rational appreciation of the economy of standardisation to have supervened. This is particularly true of the cylindrical can, where a recognised range of sizes is gradually being established in the British market, especially for the packing of fruit and vegetables.   The following table is taken from " Tinplate and Canning "[1] and gives the American and English sizes. A.10 is the " gallon " size, and as may be seen is approximately two-thirds of a gallon.

After manufacture the cans should be washed before passing to the canning line.   There are several automatic washing machines upon the market, all of which will give good service.

Reference.	Overall size in inches.		American Notation.	Capacity in c.c.
	Diameter.	Height.		
Picnic	$2\frac{11}{16}$	$3\frac{1}{4}$	211 × 302	240
A.1	$2\frac{11}{16}$	4	211 × 400	315
E.1 ..	$3\frac{1}{16}$	4	301 × 400	395
A.1, Tall ..	$3\frac{1}{16}$	$4\frac{11}{16}$	301 × 411	475
A.2	$3\frac{7}{16}$	$4\frac{1}{2}$	307 × 408	580
E.2	$3\frac{3}{4}$	$4\frac{11}{16}$	310 × 411	730
A.2½	$4\frac{1}{16}$	$4\frac{11}{16}$	410 × 411	850
A.10	$6\frac{3}{16}$	7	603 × 700	3,050

Can opening devices are legion and even a summary of the patent literature would fill a book. They are particularly popular for the shallow fish can.

Tinplate and Lacquer

Care should be exercised in the purchase of tinplate and it is advisable for the canner to specify his requirements and see that they are satisfied. The grades most generally used in Great Britain are 28 to 32 B.G., having a tin coating of between 1·5 to 3 lb. per basis box of 112 sheets, each 20 by 14 inches.

In the manufacture of tinplate, very mild steel bars are cut to suitable lengths, heated to redness, and passed through " chilled " rolls. The plate is folded across the middle, re-heated and again rolled. The re-heating, folding over, and rolling is repeated until sheets of the desired thickness are obtained—as many as thirty-two thickness may be rolled together as one piece in this way. They are then cut to size and separated. The " rough black plates " so produced should be free from streaks and uniformly coated with a black scale of oxide. This is removed by pickling in warm dilute sulphuric acid for about 20 minutes ; and subsequent washing and rubbing with sand and water. The sheets are annealed in wrought iron boxes, varying in size, at a cherry red heat and then rolled, to improve the surface and give the necessary smoothness and uniformity. The cold rolling renders the plate somewhat hard, and they are therefore annealed once more, usually in cast iron pots, as it is not necessary in the second annealing to use so high a temperature or as long a time as in the first case.[2] The sheets are now finally pickled in weaker sulphuric acid than was used in the previous pickling, and after being again rubbed with sand are immersed in water preparatory to tinning.

The tinning apparatus, or " Stow " varies somewhat with the size and quality of the plates ; with very large plates the bath of tin is contained in a basin-shaped pot, whilst with the large sizes and ordinary qualities the plates are manipulated entirely by machinery during the tinning process.

The form of apparatus consists usually of five " pots " called respec-

tively (1) the grease pot, (2) the tin-man's pot, (3) the washing pot, (4) the dipping pot, (5) the grease pot. The grease pot contains melted grease, such as tallow or palm oil, and in this the sheets are dipped until all moisture has been removed, and they are uniformly coated with grease. They are next dipped into the tin pot which contains molten tin covered with a layer of grease—the latter is increasingly being replaced by a bath of zinc chloride or " killed spirits." Here the sheet receives its first tin coating, which, however, is not perfect, and to complete the tinning the sheet is dipped into the first compartment of the washing pot, where it remains until a uniform coating is produced. The plate is taken out and rapidly examined by the workman, who wipes over the surface with a brush and to remove the marks of the brush rapidly dips the plate into the second compartment of the pot and then transfers it to the final grease pot, where it passes through a pair or a series of rolls, which squeeze off the excess of tin and improve the surface. The plates, after coating with tin, are then cleaned from grease, usually by rubbing with bran and finishing with the woolly skin of a sheep; they are afterwards separately examined for defects, and, after classification, are packed in the familiar flat wooden boxes and branded for the market.
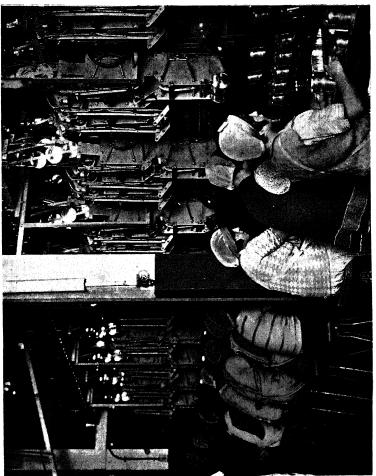
Two types of annealed plate are on the market, charcoal and coke, and there is some controversy as to which is preferable. Although there is little published evidence to warrant it, practice assumes that one type suits different foods better than the other. Certain it is that the meat canner prefers the charcoal annealed : the tin coat is said to be less porous than on the coke, but, again, experimental data are lacking. Work published by Hoar and Havenhand[3] has however given useful information upon the type of tinplate likely to be most successful in the canning of acid foodstuffs such as fruit and fruit juices. Their experiments would appear to show that, for maximum resistance to corrosion, the steel should have a low sulphur content, especially in the surface layers, and rimming steels would appear to offer some advantage : the copper content should be not less than twice that of sulphur : and the steel should be free from massive cementite. It has been said that the coating of 1·5 lb. per basis box is below the margin of safety : some workers suggest 2 lbs. to 2·25 lbs. as a minimum but there is no agreement on the subject. For meat canning it is usual to specify a charcoal plate of heavy coating and these figures will give some indication of what may be demanded. The National Canners' Association standards are given on p. 89.

The electro deposition of a thin tin layer on top of the hot-dipped layer has been studied with encouraging results.[4] It is said that the porosity can be reduced very substantially by a deposit of only 0·25 lb. per basis box. Experiments have been initiated upon the possibility of increasing the resistance of tin to corrosion, by adding traces of some other metal,[5] but so far they have given inconclusive results.

Drawn aluminium cans are said to have been successfully used in the canning of fish, but experimental work by Morris and Bryan[6] has shown their unsuitability for British fruits such as gooseberry, strawberry, etc., in sugar syrup.   Once-lacquered aluminium cans seem no better, although twice-lacquered are better.   They are of the opinion that success will depend upon the excellence of the lacquer coating even more so than does that of tinplate.

To-day it is the practice to employ lacquered tinplate in canning many fruits, particularly those containing a high proportion of natural colouring matter, in the canning of fish, especially shellfish, and some meats.   Even minute amounts of metal dissolved from the can wall by the acid in the fruit juice is sufficient to ruin the appearance and selling value of the pack, since the fruit colouring is turned to an unattractive brown even though the corrosion of the can may be infinitesimally small and the pack perfectly sound.   Pears, apricots and peaches are little affected, but the typical British fruits such as blackberries, currants, strawberries and so forth are all too easily spoilt.   Strawberries, which contain tannins, are highly susceptible to the action of iron, forming an objectionable black stain at two parts of iron per million.   Blackcurrants, rich in colouring matters of the anthocyanin group, are visibly affected by two parts of tin per million, whilst they are unaffected by 100 parts per million of iron.   Peas contain sulphur compounds which react with the tin to form a black stain.   The lacquered can is essential for many forms of shellfish.   Crustacean flesh liberates ammonia and some sulphur compounds and thus gives a black stain with the iron.

Tinplate is coated with lacquer and is purchased by the canner in the sheet form.   It has been said that Japanese firms spray the finished can, thus eliminating the danger of damage to the lacquer film inseparable, or almost so, from body making and seaming.   On the other hand, the difficulties of efficient spraying of the finished can are obvious, whereas, provided due care is exercised, the cans may be stamped rapidly and well out of the lacquered sheet without undue damage.   The modern stamping machine can be made to yield a can with unbroken lacquer, if properly manipulated, even at the rate of 150 per minute.   The first requirements of the successful lacquer are that it should be hard, elastic and firmly adherent.   The high degree of elasticity required necessitates the use of stoving varnishes of the oil-resin type, and both synthetic and natural resins may be employed.   The maximum time and temperature of stoving are one hour at 170° C.[7]; shorter times and temperatures are preferred.   The use of lacquer admits of the incorporation in it of substances that may have an inhibiting effect upon the corroding interaction between the food and the metal of the plate and/or the lacquer.   Zinc oxide, for example, is frequently incorporated in the lacquer on pea cans : this forms sulphide without discolouring effect and prevents the sulphur compounds in the peas from reaching the metal.   The problems

FIG. 18

CANS BEING DELIVERED TO THE FILLING BENCH BY WAY OF A CAN COUNTING MACHINE, WHICH
COUNTS AND THEN HOLDS THE CAN IN A CLIP READY FOR THE OPERATOR

Courtesy of "Food"

of tin discoloration from the volatile sulphur compounds from the protein of meat have been studied by the British Food Manufacturers Association. That body has overcome it by the introduction of sulphur-resistant lacquers for meat products.

Cans for canning beer and concentrated fruit juices are lacquered internally and then coated on top of the lacquer with wax : they are constructed to withstand a high internal pressure, and, by reason of the wax, are impervious to sulphur dioxide. The wax melts at 150° F., therefore the cans cannot be used for products requiring a high sterilising temperature.

Can Filling

From the washer the cans pass to the filling operation. The usual practice is to allow them to roll by gravity down a runway fitted with a device for righting them upon their base for filling. Filling may be performed by hand or machine, depending upon the nature of the foodstuff, and the degree of mechanisation of the cannery. The cans may flow down the centre of a filling table upon a belt, whence they are lifted for filling, and after filling, placed upon a second belt or conveyor for transfer to the seamer. An alternative, commonly practised in California, is for their delivery by gravity to a can counting machine situated in front of the filling operative, falling into a clip at the bottom of it at the operative's eye level, whence it is easily removed for filling. In the packing of mixtures, such as fruit salad, the cans pass the operatives on a belt, each operative being responsible for a separate ingredient. In the more modern milk canneries, the empty cans are held upside down in a metal conveyor by their bottom flanges until within a few inches of the filling machine, when mechanism comes into play to reverse them on delivery to the filler. It is obvious that whatever device is adopted the ideal practice is such as to prevent dirt and bacteria falling into the clean empty can.

The can is filled with a given weight of food and the remaining space filled with brine, sauce, syrup, gelatine solution or soup, to within a given distance of the top. The space between the liquid surface and the can top, known as the headspace, is of the utmost importance. If too great, then too much air will remain in the can, with consequences described later under the heading of " spoilage " : it will also tend to make the can collapse on cooling after retorting. If too little space is allowed, adequate provision is not made for inevitable expansion in retorting, with the result that the can will bulge, and leaks will be made in the seams, or the can will burst. Another consequence is that hydrogen " swells " (discussed later) will be caused through lack of sufficient space for the hydrogen produced through any slight corrosion of the can. The final headspace after the lid is seamed on should be from one-eighth to three-

sixteenths of an inch. When deciding on the level of the filled can, allow-
ance must be made for the countersink of the lid.

Mechanical Filling

Many foods, such as easily damaged fruit, sardines, hams, asparagus
and many others that will come readily to mind, can only be filled by
hand.   Size and shape would make it seem impossible that many of these
could be filled by hand to a given weight, but it is surprising how rapidly
operatives, particularly on fruit, can fill to a known weight.   Morris[8]
states that examination of the filled weights of a large number of cans
has shown that the average figure for soft fruits, such as raspberries and
strawberries, is 0·61 oz. avoirdupois per fluid ounce of filling space.   For
stone fruits, with their more symmetrical shape, the average is higher
at 0·65 oz.   Although some fruits pack closer than others, especially when
wet, this figure should not be exceeded by very much, otherwise the final
appearance will be spoilt.

For the same reason, in mechanical filling it is customary to fill by
volume rather than weight, and the mechanism of the machine thereby
adapts itself to various sized foods.   In the case of completely fluid foods
like soup, tomato purée, fruit juices, and milk, machines may be used
that deliver a pre-determined weight, although this is not usual.
Machines vary in operation : some deliver an automatically measured
quantity whilst, in others, at a regulated height of fill, mechanism comes
into operation to cut off the flow.   Most machines fill one can at a time,
except when fluids alone are handled : for example, it is usual to fill more
than one can of milk at an operation.   Some machines fill as many as
six cans at once.   They are delivered in line to the filler, the six then move
transversely to the delivery pipes below the holding tank, complete the
path and then travel onwards in single file once more to the seamer.
All machines should be fitted with a " no can—no fill " device, by which
the can on entering the machine operates a lever or cam allowing the
machine to deliver to the can.   If there is no can the device is not touched
and the machine cannot deliver until a can does enter.   Waste and mess
are thus avoided.

In a typical pea or bean filling machine the food is held in a hopper
under the base of which chambers or pockets of adjustable capacity pass
either in a circular or oscillating path.   The former is the more general.
The pocket carries the food round, or along, until over the open can, when
it is released by a shutter mechanism.   In some machines the pockets are
filled and emptied by means of pistons.

Recent practice fills salmon mechanically, but the weight and head-
space have to be adjusted by hand afterwards.[9]   From the filler, the cans
pass to an automatic weighing machine which discharges them to one
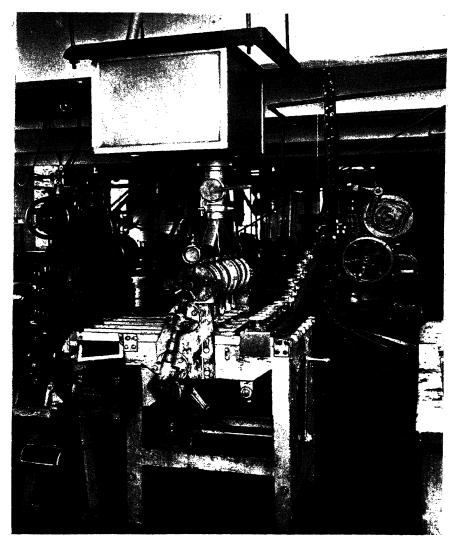of three belts, according to whether they are correct weight, under or

FIG. 19

FILLING MACHINE AT ONE OF THE SCOTTISH MILK CANNERIES.   THE EMPTY CANS ARE SEEN
COMING FROM THE UPPER FLOOR, BEING REVERSED AND DELIVERED TO THE MACHINE.   THEY
THEN PASS ACROSS THE PLATFORM OF THE MACHINE FROM RIGHT TO LEFT.   SIX CANS MAY BE
SEEN UNDER THE FILLING MECHANISM AND ABOVE THEM IS THE FEED TANK.   THE FILLED·
CANS PASS BY THE CONVEYOR ON THE LEFT TO THE BACK OF THE MACHINE FOR EXHAUSTING
AND   DOUBLE   SEAMING

Courtesy of Scottish Milk Marketing Board and " Food "

Fig. 20

AN EXHAUST BOX, WITH PART OF THE COVER REMOVED, TO SHOW THE WINDING PATH TAKEN BY THE FRUIT OR VEGETABLE CANS PASSING THROUGH IT. THE ENTRANCE FOR CANS IS SHOWN ON THE LEFT

Courtesy of Burt, Boulton & Haywood, Ltd., and the "Industrial Chemist"

[Facing page 37

over weight. The last two lots pass to "patching" tables where the errors are corrected.

Syruping, brining, saucing, and so on is usually performed mechanic-ally. Where mechanical filling of the food is practised, it is usual to instal a combined machine with the filler. Some deliver the fluid simul-taneously with the food, in others it is delivered subsequently. Which-ever is adopted, it is merely a matter of linking the mechanisms of what are really two separate operations. Simultaneous operation is usual in brining peas, but with a more viscous fluid such as sauce it is usual to employ the sequential method. There is a good deal to be said in favour of the latter for all foods. Less air is entrained, separate measuring and filling permits rapid observation of the efficiency of both machines. There is a large choice of machinery on the market and every canner has his own idea of which suits his product best.

It is common practice to fill soup, sauce, brine, gelatine and syrup as hot as possible. It assists in the economic running of the exhaust chamber. It is said[10] however that blueberries can better if they are syruped cold.

Syrup

This is made by dissolving sugar in water. The water is heated in pans made of corrosion-resistant material such as stainless steel, Monel Metal, and so on, or glass lined steel. Pipe lines and valves conveying the syrup to the filling machines should also be resistant to corrosion. Metallic contamination of the syrup means metallic contamination of the fruit, with consequent discolouration. Needless to say, the capacity of the pans must be adequate to cope with the factory demand : a four-pan battery of 4 ft. diameter pans should take care of two fruit canning lines.

The water should be heated to boiling before addition of the sugar. This avoids spoiling the colour of the syrup. The solution should be stirred until the sugar has completely dissolved. There are syrup pans on the market in which electrically driven propellers do the mixing, whilst the sugar is elevated continuously into the pan by means of a small bucket conveyor. This type is commonly found in jam factories.

The concentration of the sugar should be continually checked by means of an hydrometer. The Brix will be found the most useful, as by it the percentage can be read off directly. It should be of glass, since metal ones easily dent, and give faulty readings, and care should be exercised in its purchase to see that the stem is long enough for accurate reading. The degree Brix (°Bx) of a pure sugar solution is the percentage of sugar by weight contained in it at 20° C., and at any other temperature correction must be made of 0·9° Bx for every ten degrees Centigrade above 20° C. For example if the hydrometer reading is 55·4 in a syrup at 90° C., the following correction must be made :

$$\frac{90 - 20}{10} \times 0·9 = 6·3$$

Therefore the percentage of sugar is 55·4 + 6·3 that is 61·7.   To take the reading a sample of the syrup should be taken in a measuring cylinder, the hydrometer is then fully visible and it, and a chemical thermometer, can be used without fear of breakage.

With regard to the sugar used, much depends upon the colour desired in the final syrup.   For the palest, obviously a refined white sugar is essential.   There would however seem to be certain advantages in the case of crude beet sugar and the matter is discussed under the heading of " spoilage " later in this chapter.

Fruits vary in the strength of syrup needed for a good pack.   The final syrup will be brighter the higher the concentration of sugar, on the other hand this must be restricted to avoid a sickly sweetness and an uneconomic expenditure on sugar.   The percentage of water in the fluid, or, to put it the other way round, as is more usual, the percentage of soluble solids in the fruit affects directly the percentage in the final pack. As fruits vary in this regard, so must the sugar strength of the syrup if the pack is to be a good one.   Hirst[11] has carried out prolonged trials upon this problem at Campden and the bulletins from that Research Station upon it should be consulted.   The pounds of sugar per gallon of water varies from 6 to 10 according to the fruit, i.e., a strength of 38° Bx to 50° Bx.   Pears[10] should be blanched in citric acid solution and to the 40 per cent. syrup about one quarter per cent. of citric acid should be added.   For fancy pack peaches a 55 per cent. syrup is used in California, and on the standard pack, a 25 per cent.[12]   Colouring matter is added to overcome the browning of certain fruit, such as strawberries, Morris recommending Ponceau 2R.

Brine

In dissolving salt in water for brine, care should be taken to carry it out in corrosion resistant pans, which may be of similar type to those used for syrup.   Cleanliness of pipe lines, valves, etc., is equally important.

The usual strength employed for peas is 2 per cent. sodium chloride and 2⅓ per cent. sugar, but the amount of sugar is varied to some extent according to the grade of peas being packed, and the natural sugar content of the peas.   Among colours used for canned peas are Methylene Blue, Waterblue 6B, Patent Blue, indigo-carmine, or indanthrene blue.

Exhausting

The next stage in the process is the removal of the air in the head space, known as exhausting or " steaming."   The latter term is illustrative of the older method of achieving this object, inasmuch as the can was sent through a " steam " chest.   However it may be achieved, the result is the same : the replacement in the headspace of air by steam, which, on cooling, condenses, leaving a partial vacuum.   The ideal being as low a

pressure as possible without collapse of the can. It is an important operation : an imperfect exhaust tends to produce discoloration of the foodstuff and facilitates ærobic bacterial growth as well as corrosion of the can. Furthermore the can fails to collapse properly on cooling and it may be mistaken for a " swell."

There are several methods of exhausting. In the first and oldest, one that is in general use for fruit and vegetables, the cans from the syruper, briner, or other equivalent operation are carried through a covered tank full of hot water at a temperature of 180° to 190° F. The water should come within about an inch of the top of the open can, which passes through it along a winding path formed of a series of revolving discs, guides sending it from one to the next. Means are provided for varying the speed of travel, and the temperature of the tank. The discs are fitted with metal bushes, running on spindles which are scrolled for lubricant retention. The time of passage should be kept as short as possible to avoid risk of deterioration by exposure to the atmosphere. The usual maximum is six minutes. This point is discussed more fully in Chapter XIII.

Steam exhaustion is sometimes used. For this the lids are loosely placed on the cans and they then travel on a similar type of path in a closed box in which jets of steam play on the lids and sides of the cans. The time allowed is between thirty and sixty seconds, but Morris[8] is of the opinion that the method should not be used for fruit containing a good deal of air in the tissues, as there is not sufficient time for it to be driven off.

Another method, embodying features of both of these, is one more or less standard for meat and fish packed in sanitary cans. The lid is lightly clinched on by a clinching machine, one turn in the seamer, before the can goes into the exhaust box. The air driven off escapes through the space below the loosely fitted lid. Exhaustion should occupy from 15 to 20 minutes.

The exhaustion of the hole and cap can is effected in the retort. The lid is soldered on after filling, and the sterilising time is broken as soon as the air and the evolved sulphuretted hydrogen, in the case of meats, have been driven out of the can through the vent hole. This is immediately soldered and the can returned to the retort for sterilisation. The disadvantage of the hole and cap can is this double handling in the retort.

Vacuum Seaming

Whatever method is used it is essential that the lids be seamed on directly the cans emerge from the exhaust. Otherwise the whole object is frustrated. It is therefore not surprising that endeavours should have been made to evolve a method of seaming under vacuum, and to-day there are several forms of equipment available for this purpose. The

method is not regarded as suitable for fruit, especially when much air is entrained in the tissues, but it is now extensively employed for vegetables, milk, fish and certain types of meat products. It has obvious advantages in that it preserves the flavour and avoids the risk of vitaminic destruction. The can enters a gas-tight chamber and so operates the exhausting mechanism. A lid is then seamed on, the vacuum released and the can travels on along its conveyor. Such machines are equipped with automatic lid feed and a " no can—no lid " device. The efficiency depends upon that of the chamber closing device. They are made in sizes to suit all cans and when fully automatic have a speed of about 30 cans per minute.

Equipment is also available for sealing the hole and cap can under vacuum in a similar manner. The can enters a gas-tight chamber, is exhausted, mechanically soldered, the vacuum released and the can discharged.

Seaming the Lid

There is little to add to what has already been said under can making. It is absolutely essential that it should be carried out directly after exhausting. Most seaming machines are fitted with an automatic lid feed, which places the lid in position before the can passes to the rollers. To-day they are also fitted with a " no can—no lid " device. Another operation is a stamping mechanism for coding each can before it leaves the machine on its way to the retort.

Additional or Pre-cooking

Some goods, principally various packs of meat and fish, need more cooking than is available by the normal canning process. There is considerable variety in the stages at which this is given.

With ham and other meats it is given before filling. With ham it is only a partial cooking, depending of course on the size of the ham, and not sufficient to do more than take up the normal cooking shrinking. Such cooking is carried out in spring clip moulds which shape the meat to that of the can, so that when ready for canning the meat is most economically filled into the can.

Cahalin[13] describes two types of pre-cooking with sardines. In one, a " brine fry," the cleaned fish are cooked in wire baskets in brine, a stream of fresh water flowing into the tank to make up for evaporation. They are then packed in the usual way. In the other, a broiling process, the fish are filled into flats by hand and placed on moving shelves through which they travel through a broiler, with a capacity of 2,500 cans at a time. Through this they follow a spiral path for 45 to 50 minutes at a temperature of 450° F. through oil. On the last shelf they are inverted for the oil to drain off. They are then righted for saucing.
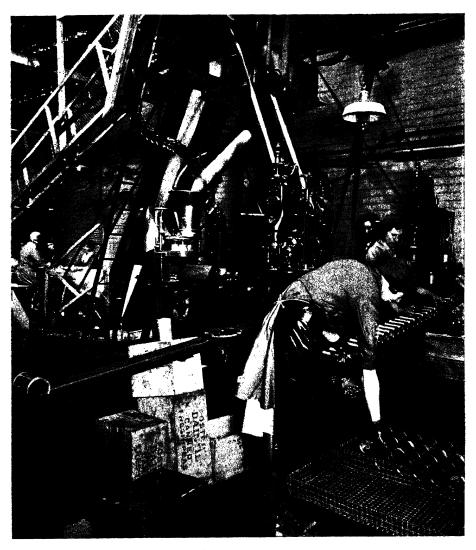
Fig. 21

THE FINISH OF A PEA LINE, SHOWING CANS BEING PLACED IN BASKETS FOR THE RETORT. FOLLOWING THE
LINES OF CANS IN THE REVERSE DIRECTION, THERE MAY BE SEEN TWO VACUUM SEAMERS, AND IN
THE CENTRE OF THE PHOTOGRAPH, THE FILLING EQUIPMENT. THE PEAS ARE INSPECTED AT THE TABLE
[ON THE EXTREME LEFT, ELEVATED TO THE HOPPER IN THE TOP CENTRE, AND THEN FALL DOWN THE
PIPE TO THE HOPPER OF THE FILLING MACHINE. THE CAN FEED IS SEEN COMING FROM THE CEILING
TO THE FILLER. THE BRINE FEED IS NOT VISIBLE

Courtesy of A. W. Foster & Co., Ltd., and " Food"

Asparagus[14] requires cooking after exhausting and seaming and before retorting. The cans are placed on iron trays and steam-heated in retorts by direct steam.

Retorting or Processing

This is a very important part of the manufacture of canned foods, and therefore it should be subjected to the closest possible scientific scrutiny and control. Upon its successful conduct there depends the making or marring of the pack, and thousands of pounds' worth of goods have been ruined through lack of attention at some point of this operation.

It is obvious that the length of time of the heat treatment must be such that all possibility of bacterial growth in the material, after cooking, must be removed, and at the same time over-cooking has to be avoided, for food that has been stewed to " rags " is unsaleable. The problem amounts therefore to one by no means easy of solution—how long must the goods be subjected to the sterilising action of the heat, and can the desirable result be achieved without over-cooking ?

There are three chief factors which control the operation. (1) The nature of the material; for example, acid fruits do not need anything like such a heavy process as meat products. (2) The variety of organisms likely to be present, and the thermal death-point of the organisms and their spores. For particulars the reader is referred to the chapters on micro-organisms. (3) The cleanliness of the premises, the freshness of the materials to be handled, upon which depends the amount of bacterial infection which has to be destroyed.

To a considerable extent the answer to (2) depends upon freshness, etc.

It is not possible to lay down a hard and fast rule as to the temperatures required to bring about a satisfactory process, for they will naturally depend upon the conditions set forth above, but in general terms fruits can be treated satisfactorily at temperatures of 100° C. or just above, and frequently just below; vegetables require at least 112° to 115° C., and potatoes a still higher temperature ; evaporated milk about 117° C., and meats not less than 118° to 120° C. These are the temperatures which must be reached in the centre of the material, which is itself in the centre of the can.

Obviously time plays a very important part, for not only must the process be continued to produce the desired temperature where it is wanted, but it must be maintained for a sufficient period to bring about destruction of the spores of the most resistant organisms which may be present. Before any process can be put into operation on a manufacturing scale, the rate at which the heat will travel to the contents of a can at the centre must be accurately determined. This brings us to the consideration of " heat penetration."

It is reasonably safe to assume that when the contents of the can at the centre have been heated to the same degree as the retort, then the

D

whole of the contents will be at that temperature. (This might not be strictly true in the case where the material consists of large pieces of such a substance as meat, surrounded by a thin liquid such as stock.) In general, if the rise of temperature at the centre of the container be recorded, a reasonably accurate indication of the temperature changes which take place will be obtained.

When a can of material is subjected to the action of heat in a closed retort, the heat can travel through the mass by two means, conduction and convection. If the contents of the can be solid, then convection currents can play little or no part, but if the contents are liquid or semi-liquid, then both conduction and convection bring about the transfer of heat. The rate of diffusibility of the heat therefore depends upon (a) the nature of the material in the can, (b) the shape and size of the container, and (c) the difference in heat head between the steam in the retort and the article which is to be processed. Methods of processing can be varied to some extent, and these will be discussed in due course.

It is by no means a simple matter to fit up laboratory apparatus which will include all the factors entering into processing on a manufacturing scale. It is of little use determining in the laboratory a set of figures, which do not find accurate application in the factory, and for this reason, it is best to construct a model retort similar in all respects to those used in the factory, or if this cannot be done, then the heat penetration tests must be carried out in a factory retort, operating under ordinary working conditions.

The electrical method of temperature measurement is the only one which can be satisfactorily adopted for the purpose, and a special instrument is now made by the Foster Instrument Co. to the design of the Food Manufacturers' Research Association. The details of the instrument can be seen from the illustration. It consists of an electric thermo-couple attached by means of a suitably insulated lead to an indicating instrument, which gives readings in temperature degrees. The case containing the indicator scale also holds an automatic " cold junction " setting device which automatically changes the setting of the pointer with changes in temperature of the " cold junction."

The thermo-couple is fixed in the can under test by means of a wing nut and a screw stem, and can be so adjusted that the thermo-junction is in the centre of the contents of the can. The actual couple itself is of very small dimensions, protected by a metal sheath which allows of its use without undue risk of damage. The lead from the thermo-couple passes through a packing gland in the wall of the retort, the gland being carefully packed to withstand the retort pressure.

By means of this instrument the rate of heat travel in a can of material can be ascertained for various positions of the can in the retort, when the can is alone in the retort or when this latter is fully packed with other cans.
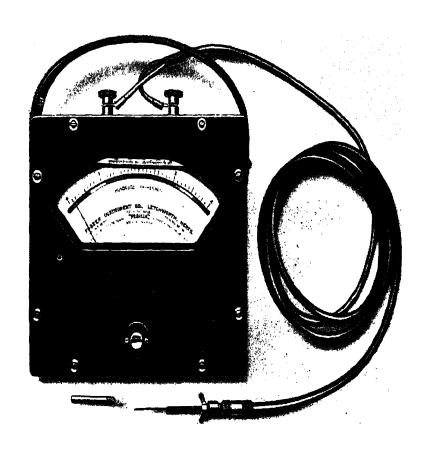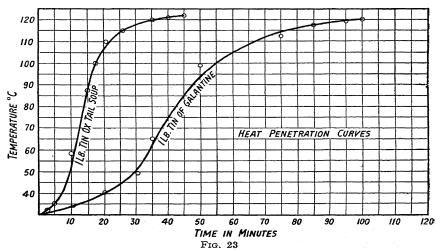
FIG. 22

THERMO-COUPLE AS DESIGNED BY THE FOOD MANUFACTURERS'
RESEARCH ASSOCIATION

Courtesy of Foster Instrument Co.

It will be found that if the steam supply to the retort is adequate and correctly distributed, and if proper provision has been made for dealing with the condensate, by means of a suitable trap, and a small vent hole left in the top of the retort for the removal of air, the packing of the retort and the position of the can in the retort will not affect the rate of heat penetration to any appreciable extent.

Retorts should be so packed that there is a reasonable space through which the steam can pass round every can. Solid packing will, of course, interfere with the free movement of the steam and entirely upset the processing time.

The accompanying curves show the rate of heat penetration of a 1 lb. tin of soup and a 1 lb. tin of galantine of ham, the former being of a liquid nature and the latter a solid. The soup reached a temperature of 120° C. in 45 minutes, the galantine needed 105 minutes to arrive at the same degree of heat.

Fig. 23

TIME-TEMPERATURE CURVES SHOWING RATE OF HEAT PENETRATION AS DESCRIBED IN THE TEXT

Courtesy of " Food "

Methods of Processing

The object to be attained is to subject the contents of the can *through-out its entire mass,* to such a degree of heat that all bacterial growth in the contents will cease, but at the same time to avoid the use of a degree of heat which is in excess of that required, in other words, to prevent as far as possible the effects of over-cooking.

The retort temperature should, therefore, not be allowed at any time to exceed the maximum temperature to which the cans are to be subjected.

This condition is relatively simple to control by the use of the instruments described in that section dealing with retorts.
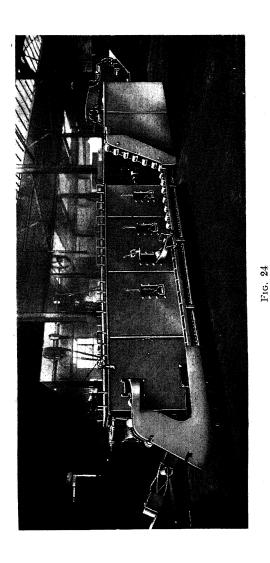
There are three methods of processing which are in common use for cans of the " sanitary " or solderless variety, and for the purpose of outlining them we will assume that the article to be processed is one which requires a temperature in excess of 100° C., that is to say, that it contains sporulating bacteria, and is not sufficiently acid in nature for its acidity to exert any marked inhibitory effect upon the propagation of micro-organisms.

The material can be treated as follows :—

(1) The temperature of the retort can be raised to the predetermined processing temperature and maintained there for a sufficient length of time to bring about the desired result (dependent, of course, upon the rate of heat penetration and cooling).

(2) The temperature of the retort can be raised to 100° C. and maintained there until the centre of the can reaches 100° C., and then the retort temperature raised as quickly as possible to the final temperature needed, and held at that temperature until the centre of the can has also reached that point.

(3) The temperature of the retort can be raised to 100° C. and maintained at that temperature for sufficient time to allow the centre of the can to reach that temperature, after which period the cans are removed to the cooler. This process is repeated at the end of 24 hours, and again at the end of a further 24 hours. This method is known as intermittent processing.
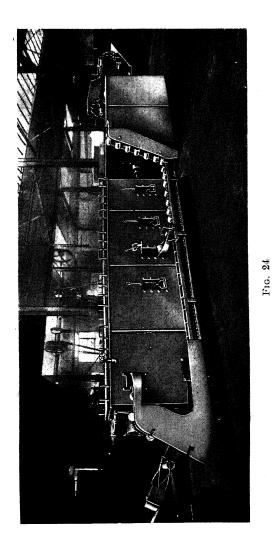
Method No. 1 possesses the advantage that the total cooking time is reduced to a minimum, and is suitable for liquid articles, such as soups, in which the contents are in circulation practically throughout the process on account of convection currents. But when consideration is given to the effect upon a can of solid matter, it will be seen that because the material nearest the walls of the can gets heated quite soon after the process is started, it will consequently be subjected to the highest degree of temperature for a much longer period than will the contents at the centre of the can, and uneven cooking, accompanied with much over-cooking of the contents nearest to the walls of the can, will result. For this reason method No. 2 is to be preferred for many kinds of foods. It is true that the total processing time will be somewhat longer than with method No. 1, but the contents of the can near the walls will not be exposed to the high temperature for anything like such a long period, and it is the temperatures above 100° C. that cause rapid over-cooking and browning of cereal materials. For solids, method No. 2 is to be recommended.

Method No. 3 : the principle underlying this is that the first process destroys all organisms present in the vegetative state, and possibly some of the spores. During the first interval of 24 hours, undestroyed spores

Fig. 24

A CONTINUOUS RETORT. THE CANS ENTER AT THE LEFT, ARE ELEVATED TO THE TOP, TRAVEL THE ALLOTTED
PATH, LEAVE BY THE DOOR, AND ARE CONVEYED TO THE COOLER ON THE RIGHT

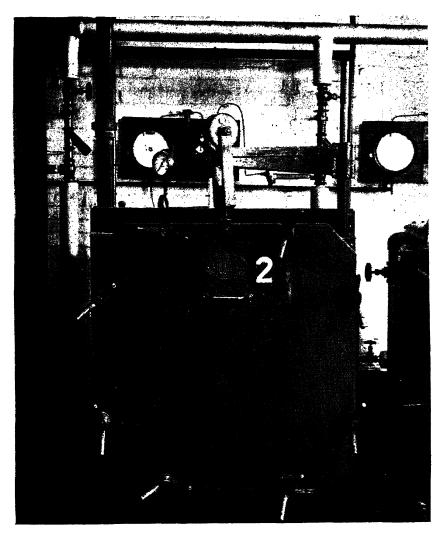*Courtesy of Messrs. F. J. Ballard & Co., Ltd., and " Food "*

Fig. 24

A CONTINUOUS RETORT. THE CANS ENTER AT THE LEFT, ARE ELEVATED TO THE TOP, TRAVEL THE ALLOTTED PATH, LEAVE BY THE DOOR, AND ARE CONVEYED TO THE COOLER ON THE RIGHT

Courtesy of Messrs. F. J. Ballard & Co., Ltd., and "Food"

FIG. 26

A SMALL HORIZONTAL RETORT, OF A TYPE IN VERY GENERAL USE IN GREAT BRITAIN

Courtesy of A. W. Foster & Co., Ltd., and " Food "

Fig. 27
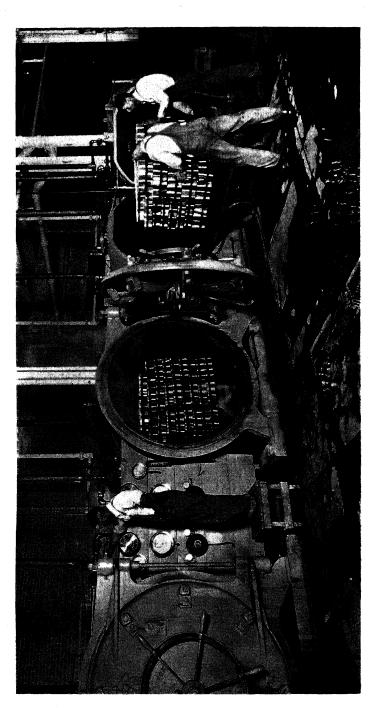
HORIZONTAL RETORTS BEING LOADED WITH ASPARAGUS IN THE SACRAMENTO CANNERY OF THE CALIFORNIA PACKING CORPORATION. THE CLOSING MECHANISM IS CLEARLY SHOWN ON THE DOOR IN THE CENTRE, WHICH ALSO SHOWS THE STEAM CIRCULATION ROUND THE CANS

Courtesy of "Food"

[*Facing page* 45

will develop into the vegetative form, and possibly produce a few spores. The second process will destroy these vegetative forms, leaving behind only a few spores to develop. These, in their turn, change to the vegetative form and are destroyed by the third and final process. On account of the extra labour and steam required, this method should be avoided except in special cases. It finds some application in the handling of articles containing sugar and needing care in regard to temperature, lest the sugar be partially converted into caramel.

Retorts

There is a variety of retorts available and they may be divided into two main classes : continuous and intermittent. The latter may be further subdivided into horizontal, vertical and rotating.

The continuous type is particularly suitable for fruit and vegetables, as they are processed at lower temperatures. As the name implies, the cans flow through the retort continuously. The time of the cook is determined not by the speed at which the machine is driven—that is kept constant—but by the length of the path the can follows. Doors are provided in the side of the retort, the number varying in accordance with the size of the cooker. The door at the appropriate distance from the entrance is opened and the can leaves by it. The illustration will make this clear. The cans travel through a tank of water boiled by closed and open steam coils. In some cookers the cans are rotated to facilitate the penetration of heat, a specially advantageous device with foodstuffs containing large but movable masses like tomatoes or peaches, when there is interference with convection currents. In such retorts the weak point is obviously the valve mechanism whereby the cans are transferred to the interior. The danger of a jam or breakage ruining the cook cannot be overlooked, and care must be exercised in operating.

Compared with this the intermittent type would seem to need a good deal of additional equipment. First of all there are the baskets or trays to hold the cans, hoists for hoisting them into vertical retorts or trucks for carrying them to horizontal ones. On the other hand, there is no internal mechanism to jam and ruin a batch. The rotating type may be in either of two forms. In the Danish the complete retort rotates upon trunnions, in the British the cans, properly secured in trays to a horizontal axle, rotate within the stationary retort. This type is essential for viscous fluids, such as evaporated milk, where violent agitation is essential to obtain adequate heat transfer and maintain homogeneity of the fluid product. The illustrations should give all the information necessary to gain an adequate idea of the retort types: capacity and cost may be more profitably obtained from the manufacturers. Once the cans are in, the door is closed or the lid shut and bolted, and the steam turned on. On the completion of the cook the pressure is released and the cans withdrawn, when they must be immediately cooled.

Cooling

The rate of cooling needs almost as much consideration as that of "retorting," for "cooking" will continue until the temperature has dropped below 70° C. The time of cooling must be considered for every article and shape and size of container.

Cooling should be brought about as rapidly as possible, and therefore artificial means are invariably employed except in the case of goods sealed in glass containers, where air cooling is usually resorted to; otherwise, the strain brought about by the rapid contraction of the glass will lead to fracture. A moment's consideration will show that if the temperature gradient maintained during heating were to be reversed, then the rate of cooling should be almost the same as the rate of heating. This is not strictly true because the materials in the container will have undergone a change which is likely to affect the rate of heat travel through them. This applies particularly to articles containing a cereal for, upon the application of heat, it will lose its granular structure and become a mucilage, the heat conductivity of which will be different from granules of starch in a liquid such as water. As in the great majority of cases, rapid cooling is the object desired, the small difference that arises in rate of heat loss through change in the consistency of the article can be ignored.

When the processing has been conducted in a steam-heated retort under pressure, cooling may be said to commence at the time that the steam supply ceases and the relief valve on the retort is opened to permit a return to atmospheric pressure. This operation must not be carried out too rapidly, for a sudden reduction in the pressure outside the can may lead to its bursting.

When the pressure has become normal, the retort is opened and the cans removed to the cooling plant. This may consist of either a spraying device or cooling by immersion in a bath of running cold water.

Spray cooling is by far the most rapid and therefore the best method to be adopted. The trays of cans are placed upon a movable chain belt which passes through a spray chamber so arranged that jets of water impinge upon the cans from all directions. The speed of the belt can be regulated to suit the size and shape of the containers. Where the cost of water is a serious item, it can be arranged for it to drain into a sump after its passage over the hot cans. From thence it may be pumped through a refrigerating unit, and used over again. Where the cost of water is a secondary consideration, it will be found that the temperature of the main supply is usually low enough to do all the cooling that is necessary. The chief reason why spray cooling is so much more efficient than immersion cooling is because every droplet of water that comes into contact with the hot can at the earliest stage of cooling is converted into steam, and the latent heat thus absorbed by the conversion of the water into steam produces a very rapid change of

Fig. 28

A BATTERY OF VERTICAL RETORTS, OPENED, SHOWING THE METAL BASKETS FOR THE CANS

THE CONTROL DIALS ARE PLAIN TO SEE

Courtesy of Burt, Boulton & Haywood, Ltd., and the " Industrial Chemist "
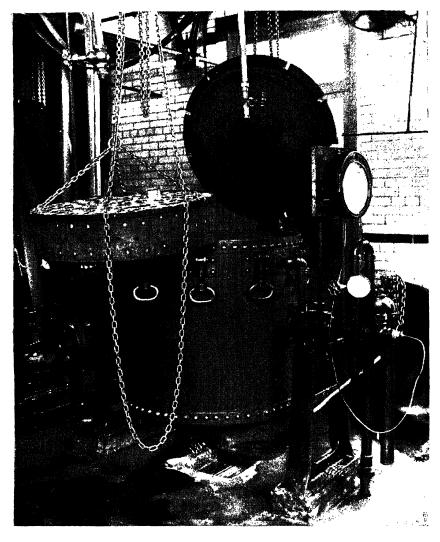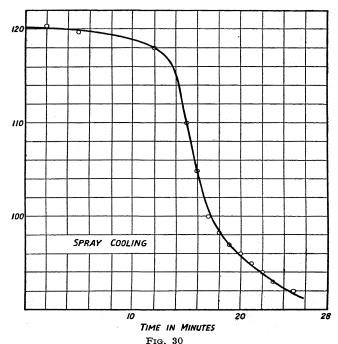
FIG. 29

A ROTATING RETORT OF THE DANISH TYPE. THIS SHOWS CLEARLY
THE STEAM SUPPLY, AND THE DISTANT THERMOMETER ENTERING
THE TRUNNION

Courtesy of Scottish Milk Marketing Board and " Food "

heat in the contents of the can. It must, however, be borne in mind that where that article is solid the heat at the centre has to be conveyed by conduction to the outside of the container before the spray water can be effective. When the contents of the can are liquid then convection currents also play a part. Therefore the same conditions apply as in the case of heating, that is to say, the rate of cooling depends upon the size of the container, and upon the nature of the contents. The finer the spray and the greater the air current in operation, the greater will be the rapidity of cooling.

FIG. 30
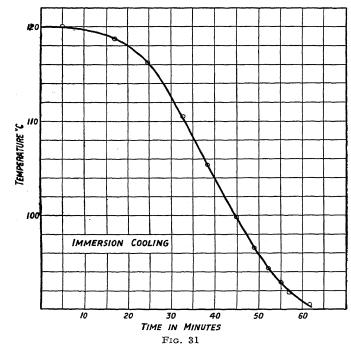
FALL IN TEMPERATURE BY SPRAY COOLING AS DESCRIBED IN THE TEXT

Courtesy of " Food "

In the case of immersion cooling, the containers may be placed on a travelling belt which passes through a tank of cold water which is flowing in an opposite direction to that taken by the belt. When this method is adopted, latent heat plays little or no part, and the rate at which the container parts with its heat is dependent upon conduction and/or convection.

A study of the accompanying curves shows the very marked difference in the rate of cooling taking place in a tin of brawn by the immersion and

spray methods. At the end of ten minutes, the spray-treated can had reached a temperature of 90° C., a loss of 20° C. from its initial tempera-ture. In the same period the immersion treated can had lost only 5° C. It should be noted that as the spray-cooled can becomes cooler, the rate of loss of heat is much slower ; this is, of course, because the part played by the latent heat becomes smaller and smaller as less and less of the water is converted into steam.

Fig. 31

FALL IN TEMPERATURE BY IMMERSION COOLING
THIS SHOULD BE COMPARED WITH FIG. 30

Courtesy of " Food "

At one time a method of flooding the retorts with cold water was occasionally used, the tins being allowed to remain in the retorts, until they were cold enough to be removed. The great disadvantage of this method was that not only was the heat removed from the cans, but also from the walls of the retort, so that the rate of cooling was even slower than by immersion. As in the case of heat penetration, cooling rates should be determined for every kind of article and for every variety of container employed, and due consideration given to the data obtained when fixing the correct process.

With some modern vertical retorts, cooling under pressure is effected by discharging the cans from the bottom into a column of water, the cans then being under the hydraulic pressure of the column. By this means internal and external pressure are equalised. As the cans pass out upwards from the water, the pressure due to the column correspondingly decreases and the necessary equilibrium is maintained until atmospheric pressure is reached.

With the continuous retort the cans are usually continuously delivered to a cooler which may be of any of the types described above.

External Lacquering

When canned foods are intended for export, or when they are supplied under a long period guarantee, extending to years, it is advisable to lacquer the external surface of the cans. Some manufacturers apply the lacquer for decorative purposes. The lacquer serves as a protective coating against external corrosion.

The lacquer is applied in a cold state, and as it is made specially for the purpose by the use of a spirit of low volatilisation point, the application of heat is not required.

The cans are removed from the cooler while still just warm, and either allowed to dry off in the air, or are passed through a chamber through which is being driven a current of warm air, the object of this treatment being to dry the outside of the cans before they pass to the lacquering machine. They are fed automatically to this machine, which consists of a slowly moving roller fitted with prongs to hold the cans. As the roller revolves it submerges the cans in a bath of lacquer, and then drops them upon a slowly travelling draining rack, which operates in a current of warm or cold air. By the time the cans reach the far end of the rack the lacquer is dry and labels may be affixed. In fact the cans may be made to pass automatically to the labelling machine.

Storage

It must be understood that cooling is not carried out to the temperature of the cooling water. The cans should retain enough heat to dry them in the air on their way to storage. Adequate cooling is essential, otherwise, when the cans are stacked in the store, being too hot, they will cool too slowly, the food will be over-cooked and spoilt. Furthermore, this " burning," as it is appropriately termed, will accelerate corrosion of the can. It is usual to stack the cans so that there is a free space round them for circulation of air. Although a matter of factory routine, varying with every factory, it is advisable to arrange them according to a plan, so that old stock does not accumulate whilst fresh cannings are sold and dispatched. Before delivery to store, it is a matter of routine in most canneries for the cans to be coded individually so that they may

be identified by batch and date.   As already noted, this may be done at the seaming machine.

Too little attention is paid to the necessity for keeping the atmosphere in the store as dry as possible.   Moisture-laden air can be extremely harmful to the external appearance of the cans by promoting corrosion and rusting.   Maintenance of a constant temperature is similarly important for two reasons.   In the first place, a sudden drop in temperature may chill the air below the dew point of the moisture in it.   This will condense on the cans with disastrous results.   Secondly, temperature changes will damage the quality of the contents of the cans.   This is particularly liable to happen if, for one reason or another, stock has to be stored for any length of time ; several temperature changes are obviously more dangerous than only one.

There is much to be said in favour of storing in artificially cooled chambers.   Rendle[15] has given it as a matter of experience that canned soft fruit should be so stored.   The chemical and physical changes that may result during storage to the detriment of the pack may be prevented, or considerably arrested, in this way.   Cans of fruit stored at normal atmospheric temperature for some months compare unfavourably with similar cans which have passed a like time under artificially cooled conditions.   Joslyn[16] states that the life of canned orange juice is at least trebled by storage at 32° F. as compared with storage at 68° F. The same would appear to be true of other fruit juices and many canned soft berries.

Labelling

This may be intermittent or continuous.   With the non-cylindrical can, each can has to be labelled individually, although by machine.   In other words, the can is picked up by hand, placed on the machine, the machine then places a ready gummed label in place, wipes it on, releases the can and the operative places it on the conveyor, or in a tray, for transfer to the boxing department.   The maximum speed attainable by skilled operatives is said to be about 1,800 an hour.

For the cylindrical can there are several machines available of much greater speed, 7,000 per hour being an often quoted figure.   The machines are completely automatic, the cans rolling through them down a slightly inclined belt.   The movement enables them to pick up a waiting gummed label, and roll it round the can.   Still rotating, the cans pass between tightly stretched belting which presses the label securely on.   The labels are strips that completely lap round the cans, and it is surprising how easily such machines can be kept adjusted to fix the label " in register." The operation is essentially a wrapping one as against what might be termed the dabbing and wiping one of the individual labeller.   The latter, however, can be adjusted to fix almost any shape of label and in almost any position on the container.   As cylindrical cans are not usually labelled

in this way and their shape enables them to be handled on the speedier, continuous machine, the individual labelling machine is only used for eccentric shaped containers and finds its principal employment in the labelling of bottles and jars.

The labelling room or department should be given special attention, which will be fully worth while. Gums and pastes are tricky substances to deal with and most erratic in their behaviour under adverse atmospheric conditions. There is nothing so galling as to find, after labelling several thousand cans, that all the labels have fallen off, or their ends are flapping in the breeze. No matter how much skill, care and labour may have been spent in compounding an adhesive, a change in the weather may alter both temperature and humidity in the labelling department to such an extent as to ruin all one's efforts. There are only three things to do. Wait for a more propitious day, send out a pack below standard, or avoid the trouble altogether. And the only way to do this is to condition the air. Those who have adopted this way of overcoming their troubles have never regretted it. On a seasonal pack, such as fruit or vegetables, it probably will not be worth undertaking : they are canned and may be delivered to the wholesale trade before weather conditions become too difficult. But in meat and fish canning in Great Britain it is certainly worth while.

Spoilage

Canned goods may be ruined by three chief causes : micro-organic destruction, corrosion of the container and faulty operation in the cannery.

The last of these may be dealt with first. The can may be damaged by overfilling it, denting it, or allowing it to rust, and the remedy is obvious. The contents may be " burned," as described earlier in this chapter, either by stacking the cans before they have cooled adequately, or by over-processing. Again the remedy is obvious.

Bacterial Spoilage. Although this is dealt with in later chapters, a note here will not be out of place. It comes about through inadequate sterilisation, the micro-organisms and their spores not having been destroyed, or through the use of leaky cans. On cooling, organisms are drawn into the can through leaks in the seams. The methods of testing for leaks are described later. The result is that known as " flat sours." The cans partially collapse and, on opening, the contents are found to have " soured," i.e., fermented. The organisms responsible would appear to be thermophilic spore-forming, non-gas-forming bacteria. The trouble has been particularly damaging to American pea canners and a good deal of work has been carried out in the U.S.A. More recently, McMaster has investigated the problem at Campden[17] and isolated flat-souring organisms of the facultative ther-

mophilic type from canning sugars used for peas and from pea blancher water. They survive sterilisation at practicable working temperatures and will grow at 37° C., hence they cause spoilage under normal conditions of storage. The remedy is to use sugars free from spores and maintain scrupulous cleanliness of the plant, particularly the blanchers, and the peas should be washed thoroughly after blanching.

Another form of micro-organic spoilage arises in fruit from a mould, *Byssochlamys fulva,* the spores of which are very resistant to the sterilising process. Spoilage takes the form of complete breakdown in the texture of canned fruit, so that on slight shaking it disintegrates completely, leaving an unpleasant cloudy fluid as the sole content of the can. The can may bulge somewhat, but as often as not it appears upon external inspection to be perfectly sound. Sterilising temperatures should be such as to give a temperature of at least 190° F. and preferably 195° F. in the centre of the can.[18] The mould is widely distributed in fruit orchards and plantations, and control in the field would appear to be impracticable; for the canner's purpose for the majority of materials, the attainment of a high temperature during sterilisation is more satisfactory than long cooking at a lower temperature. To reduce infection in the factory, fruit trays, belts and utensils should be swilled regularly with boiling water. (See Chapter XV.)

Corrosion of the Container. The literature upon this subject is extensive and the reader should refer to the authorities quoted for more detailed information than space permits in this chapter. Corrosion takes two principal forms, rusting of the iron of the steel plate and electrolytic decomposition of the tinplate with the formation of gaseous hydrogen which causes hydrogen " swells."

The former is less general and there are comparatively easy ways of avoiding it and preventing spoilage of the pack. It has been found in fruit salad, prepared by mixing and reprocessing imported fruits,[19] in some fruit, gooseberries and vegetables. It takes the form of a light brown stain upon the tinplate, appearing first on scratches and flaws on the can ends, particularly the lid. It is not so noticeable in lacquered cans, being obscured by the colour of the lacquer. The cause is formation of rust between the iron and the oxygen in the headspace in the presence of carbon dioxide. The chief source of the last is probably the fruit tissues, and another the water used to make the syrup. The determining factor is the ratio of carbon dioxide to oxygen: staining proceeding most rapidly during the first day of storage when the oxygen is at its maximum. When the ratio exceeds 1·0 to 1·1 the reaction ceases. Efficient cooling is an important item in prevention: the cans should be inverted after one week's storage, and it may conveniently be done during labelling and casing. The rust formed on the lid is dissolved by the fruit acids, and no rusting will take place on the inverted bottom, as the carbon dioxide: oxygen ratio has increased sufficiently.

Hydrogen Swells

Most canned foods develop these upon prolonged storage owing to the liberation within them of increasing volumes of hydrogen. Although loss from this cause is greatest with fruit, it occurs with other foods. Various means of lessening the effects have been suggested, and there are a number of factors that may be utilised to inhibit artificially what is a progressive and apparently unavoidable cause of spoilage. The vacuum in the can is most important. With those foods, fruit, and to a less degree vegetables, the vacuum should be from eight to fourteen inches of mercury. It is influenced by the time and temperature of the exhaust and the initial volume of the headspace. A high vacuum has the advantage that swelling must develop more slowly as the hydrogen formed must replace the vacuum before sufficient pressure is developed for " swelling." A higher vacuum is produced, the smaller the headspace; on the other hand, the headspace is governed by the necessity to allow reasonable space for the hydrogen formed as well as for the expansion of the food during retorting.

The can bulges from the pressure within it of hydrogen liberated from the attack upon the metal by the acid juices of the foodstuff. In the early stages the swelling can is referred to variously as a " springer " or " flipper." The final stage is perforation of the can wall, giving a " blow." The phenomenon is observable in plain tinplate cans, and in once- and twice-lacquered cans. Lacquered cans perforate more frequently than the plain, although they are superior in other respects.

The acid juices penetrate the porosities in the tin plating and the tin and mild steel form an electrolytic couple. Tin or steel may be the cathode under suitable conditions. Carrasco[20] is of the opinion that in tinned sheet containers corrosion is always taking place and that what is needed is investigation of the velocity of this corrosion and the factors influencing it. The corrosion is assisted by secondary electrochemical reactions, originating between the iron and the impurities included in it as separate phases. In the simplest and most favourable instances, the hydrogen liberated accumulates on the iron, and the process tends to be arrested by cathodic polarisation, but the iron dissolves continuously, the surface layer being renewed more or less rapidly and the hydrogen leaves the metal surface, permitting new ions to be liberated from the surface. The presence in the foodstuff, or in the steel, of sulphur compounds, increases markedly the velocity of corrosion. Morris has arrived at similar conclusions,[8] as also has Hoare,[4] who is further of the opinion that another factor is the layer of tin-iron compound always present between the steel and its tin coating. Carrasco[20] has examined the effect upon corrosion of the chemical and physical quality of the mild steel of the can, and concludes that the velocity of the corrosion phenomena depends greatly on the tinned sheet and more on the quality of the steel

than on the thickness of the tin layer protecting it. The work of Hoar and Havenhand,[3] previously referred to, would seem to emphasise this point almost quantitatively.

Morris[8] has investigated the corroding effect of the preserved food, particularly in connection with fruit. Tin is slowly dissolved by fruit acids when in contact with iron, the attack being greatest at low acidity, while the attack on the iron is greatest at high acidity. In the presence of air this attack proceeds in an increasingly acid medium : that is, the acidity at which tin is removed most rapidly from tinplate depends upon the quantity of available oxygen present in the material to which the tinplate is exposed. This points to the necessity of extracting the utmost possible amount of air from the can : the food should be as free as possible from entrained air and the headspace kept as small as conditions permit. The efficiency of the exhausting process is of paramount importance. Morris suggests that there may be, with every food, an acidity which most favours the formation of hydrogen swells and perforations : and that a change in acidity either way may result in its reduction. It has been shown, for example, that cherries, prunes and greengages form swells less rapidly when the acidity is increased.

Prediction of probable corrosion from knowledge of the acid content of the fruit is impossible. Apples, for example, containing less than one per cent. of maleic, are more liable to effect corrosion than cherries, containing about 1·3 per cent. Although vegetables are much less corrosive than fruit, they may contain more acid ; spinach, for example, may contain as much as three per cent. of oxalic acid. Morris[21] gives some interesting experimental results of the corrosion of steel by fruit extracts : although cherry extract is of low acidity, it yielded high figures for corrosion and production of swells : rhubarb extract formed a bronze coloured deposit at p_H 3·1 which stopped further corrosion, and a loose, yellow deposit, when buffered with sodium citrate to p_H 4·07, which was non-protective. Hence acidity alone can be considered as no criterion for hydrogen production.

Morris and his co-workers have undertaken considerable work upon the inhibition of corrosion. Beet sugar has been found to contain an inhibitor : this effect is not due to the sucrose, which is only a weak inhibitor. It is particularly abundant in beet molasses and brown beet sugars. He recommends[21] the carrying out of preliminary " immersion " tests with the sugars, supposing it be desired to use a mixture, both before and after mixing to make sure that inhibitors are present in sufficient quantity. Blackberries, he notes, respond to neither addition of acid nor inhibitor. Cane sugar, inverted with acid, has an inhibiting action, and Morris considers that an inhibitor is then formed. Agar-agar and beet sugar have an inhibiting influence. Gelatine is a powerful inhibitor at high acidity, p_H 2·4, but the effect is negligible at p_H 5·5. Although small quantities of inhibitor are effective, addition above a certain

concentration has little effect. Sulphur dioxide appears to vary in its effect according to the acidity, accelerating corrosion at high acidity and retarding it at low.

The effect of lacquer, as already mentioned, seems to be to increase the production of hydrogen swells and blows. According to Hoare[4] there is reason to suppose that discontinuities in the lacquer coat will preferentially occur at discontinuities in the tin coat. This may be due to surface tension factors operating during the spread of the lacquer. Though lacquering may cure evils resulting from attack on the tin, it may actually enhance attack on any exposed steel base.

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THE CANNERY LABORATORY AND ITS WORK

THE immense amount of knowledge acquired during the past 25 years or so, in regard to the nutritive value and other properties of foods, is making its effect felt in legislative changes primarily intended to benefit public health. As a direct consequence, all branches of food production, from the growing of the raw materials to the manufacture of the finished articles, are fast becoming highly specialised industries needing scientific control. This control is already in being in many of the larger and a few of the smaller concerns, but very many of the latter have not yet fallen into line—in some instances through lack of foresight and in others because the desire or ability to find the necessary capital for the equipment of a laboratory has been lacking. It seems inevitable that many firms who now struggle along by rule-of-thumb methods will find it greatly to their advantage to appoint a chemist—who will of course need a reasonably well equipped laboratory. In such a business it is probable that a start will be made in a small way, and it cannot be expected that technologists of great experience will be attracted to undertake the work. Rather will it be the newly graduated scientist, with little or no experience in an industrial concern, who will secure the appointment. To him in particular the following remarks are addressed in the hope that he will be able to avoid some of the pitfalls likely to await him.

Scope of the Work

It should be remembered that the job exists only because it is a commercially sound proposition, and a chemist, if worth his salt, must be much more than a routine analyst, although, of course, quite a lot of analytical work will have to be done. The scope of the work should be very wide, and can roughly be classified as follows :

To examine all kinds of raw materials used in the production of the articles made.

To establish close scientific control of manufacturing processes, and to study the principles underlying such processes, with the object of introducing improvements, both in quality and cost of production.

To devise new methods, and possibly new products.

To minimise waste by finding out how waste materials can be turned to good use.

Fig. 32

A MAIN LABORATORY, SHOWING THE ARRANGEMENT OF BENCHES INTO BAYS AT THE GLAXO LABORATORIES
THE SINK FITTING CAN BE CLEARLY SEEN

Courtesy of Glaxo Laboratories Ltd., and "Food"

FIG. 33

FLOOR PANELS REMOVED TO SHOW SERVICES IN THE CENTRAL
CORRIDOR IN DERBY RESEARCH LABORATORIES OF L.M.S. RAILWAY.
THE LEADS TO SEPARATE LABORATORIES ARE CLEARLY SHOWN

Courtesy of London, Midland & Scottish Railway Co., Ltd., and the " Industrial Chemist "

To keep a watchful eye upon the finished products, to ensure that they are of the best possible quality compatible with selling price, and to see that they are in accordance with the Sale of Food and Drugs Act, or with other laws which control the sale of food.

To ascertain the cause of faults in manufacture, which invariably arise in all factories, and, if possible, to suggest the remedy for their r emoval.

Other items which do not fall under any one of the above headings will probably be met, for the chemist is quite often called upon to perform quite extraordinary tasks which need both tact and initiative.

Even though he may be convinced in his own mind that he knows quite a lot more about a certain operation than does the foreman in charge, the newly appointed chemist should be shy of saying so. He should first of all try to find out in friendly conversation just how much the foreman does know, and then at some later date put forward suggestions as to how he thinks this or that operation could be improved. Much more can be achieved in this way than by trying to force new methods upon an individual who has quite probably been in charge of a particular piece of work for many years, and who not unnaturally feels that he knows all that there is to be known about it.

The chemist must do all that he can to avoid being regarded as a "swollen-headed" outsider whose efforts are to be baulked on every possible occasion. Co-operation and true *esprit de corps* are absolute necessities if good results are to be obtained.

Wherever possible it is advisable to be reasonably certain that a suggested alteration in a method of production is likely to be successful before it is put into operation on a manufacturing scale, and experiments should be conducted to this end. Alterations in production methods invariably mean some disorganisation in the factory until they have become familiar, and nothing is more upsetting to the smooth working of the factory as a whole than having one or more departments " all at sixes and sevens." It quite frequently happens that a new method cannot be tried out without alterations to the plant, and these are likely to be expensive. Consultation with the engineer may be the means of devising a small model with which the new method can be tried out in the laboratory. If this is successful, the alteration to the manufacturing plant can be carried out with a reasonable degree of certainty that failure will not result.

The chemist, if he is to do his fair share in the earning of dividends, should " have his fingers in every manufacturing pie." What is more, he should be fully familiar with all practical operations in the making of the products with which his employers are concerned. This aspect of his work is of great importance, for unless he is in possession of such knowledge it is quite impossible for him to diagnose faults when they arise, or suggest remedies for them. The work in a canning factory may be divided into

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two more or less distinct categories, technical and non-technical. The former predominates.

All technical manufacturing operations should be under the control of the chemist ; attached to his staff should be supervisors who have had some general scientific training. It is not essential that they should have had actual experience in the particular job they are to control ; this will quite readily be acquired if their minds have been trained along scientific lines. The functions of these supervisors are to control the technical operations of the factory, and should be quite distinct from control of labour. This may well be left to the foreman, whose job it is to see that employees do as they are told. These assistants can quite usefully be called " process supervisors," and they must be held responsible for the satisfactory working of the part or parts of the process which it is their job to control.

There are quite certainly functions additional to the above which the chemist will have to exercise from time to time, but those mentioned are sufficient to indicate that he should be a man of many parts.

It is obvious that, in order to exercise the control indicated, he must fully organise his work, so that no time will be wasted in going over ground previously explored, or in repeating tests or routine analyses carried out on previous occasions, details of which have been either forgotten or mislaid.

The chemist, to succeed, must be in the friendliest possible relations with his directors, the factory management responsible for general organisation of labour, etc., the engineering staff, the buying department, and the sales organisation. Although in one sense he is a " watch-dog," he must carefully avoid giving the impression that he is a policeman. Quite definitely, the realm of the works chemist lies as much in the factory as in the laboratory, and he must be prepared to act as technical adviser.

The Chemist's Golden Rule

All reports should be recorded in writing ; never trust to verbal communications, for sooner or later they will give rise to disputes.

All the above entails work " with a capital W," and what is more, systematic work. The chemist should make a golden rule, *never to be broken ;* it is : commit everything possible to writing, never make verbal reports, or, if they must be made, confirm them with a written statement, even of what appear to be the most trivial items. There have been many heartburnings caused by mistaken or misinterpreted verbal statements.

An accurate laboratory record must be kept of all work done, and therefore every sample received for examination must be entered with particulars of date and time received, who from, and what the sample is supposed to be. Every detail of its analysis must also be recorded, and in such a manner that it can be referred to in the space of a few minutes.

The date and full particulars of any report made upon a sample should also be entered, and again in such a manner that the details can be quickly turned up.   Unless this be done, no true and useful history of the work carried out can be available.   These remarks apply to investigational work as well as routine analyses.   It so very frequently happens that much of the work of this nature entails making experiments which are failures, but even if they are, full details must be kept.   In due course a problem closely allied to one formerly tackled and solved, will come along, and a great deal of useless effort will be saved if, upon turning up records, it can be ascertained that the application of this or that principle will be no good, because it has been tried out and found unsatisfactory. Experience has proved, time after time, that detailed experimental records are of inestimable service, and although the completion of such work in a get-at-able form means hours of labour, it is worth it always.

Laboratory Organisation

The general organisation of laboratory work, factory process control and keeping of records are all extremely important items.   While it is not possible to lay down a detailed scheme for all kinds of works, the following will be found to be generally applicable.

The analytical work of the laboratory can be usefully divided into two sections, (1) routine analyses, and (2) special analyses.   In the former category are included the examination of raw materials ;   analytical control of the manufacturing processes, which entails the regular drawing of samples from the materials at progressive stages of production ;   the analysis of finished products, both those made on the premises and similar articles produced by competitors ;   samples of boiler feed waters, fuels, coals, etc., from the engineering department.   The sum of all these will probably amount to hundreds, and possibly thousands, per month, and efficient organisation is essential if due benefit is to be derived from the results obtained.

Raw Materials

No matter how perfect the organisation in a factory may be, satisfactory results cannot be obtained unless the raw materials are suitable for the purpose in view.   It is therefore essential that the chemist should so organise his work that all raw materials of almost every kind should be subjected to analytical examination.   Every parcel of goods purchased that can be analysed should receive the chemist's certificate before the factory is permitted to use them.   Further comment will be made upon this aspect of the chemist's functions.

It is quite probable that it will be found, when such a system is at first put into operation, that a number of parcels of materials will have to be adversely reported upon, in which case the consignment should be

rejected and returned to the vendor, or a suitable rebate in price demanded. This will only last a short time. When it becomes generally known to suppliers that a systematic examination of all raw materials is being carried out, vendors will be careful to make sure that parcels of goods are in accordance with the specification and sample they sent in when soliciting the business. It is not to be inferred that vendors as a whole deliberately attempt to sell inferior goods. In many cases they are merchants and not manufacturers, and have to rely upon the integrity of others in regard to the materials they handle. There are very few articles needed in a food factory to which this system cannot be applied, with surprisingly beneficial results.

The actual purchasing is usually in the hands of the buyer, who is out to get articles of the standard and grade required at the lowest possible price, and it is up to the chemist to see that the materials purchased are exactly what the buyer believes them to be, that is to say, that they comply with the specification. Close co-operation is therefore very necessary between chemist and buyer. A system which will be found to work quite well is that when a purchase is contemplated samples of the particular article are submitted to the laboratory by the buyer, and these are analysed. When the bulk consignment is received the storekeeper sends a fair average sample of it to the chemist, and he examines it with a view to ascertaining if it complies in every respect with the buying sample, upon the quality of which the purchase was made. If so, he issues a certificate to that effect, and the storekeeper is thus informed that he can issue the material to the factory for use.

There is also another point of contact between the buyer and the chemist. Goods have sometimes to be bought to comply with a definite specification, peculiar to the conditions of manufacture, and it is very essential that an examination of all consignments of this kind should be made to ascertain that they reach the particular standard required.

The responsibility rests upon the chemist to satisfy himself that all the materials purchased to be used in manufacturing comply with the Sale of Food and Drugs Act, and that by their employment his firm need have no fear of infringing the Act.

In an organisation where large quantities of materials are purchased under contract, the buyer is naturally guided by considerations of quality and price, and nearly always the purchase is decided upon a sample submitted with the tender. These samples should be handed to the laboratory for report, and the report should have an influence with the buyer when deciding where his order is to be placed.

Process Samples

In regard to " process " samples—that is, samples of semi-manufactured articles, examined to ascertain if the process is proceeding along
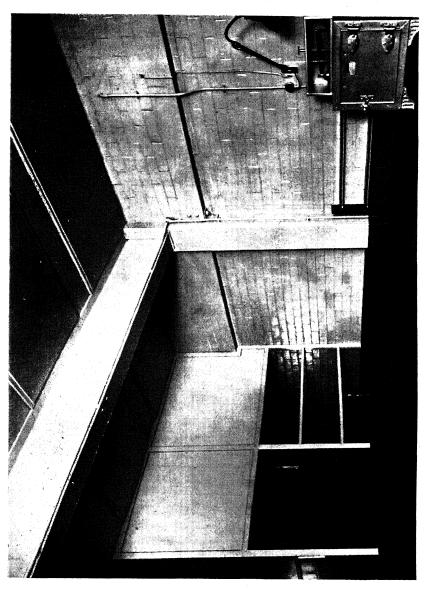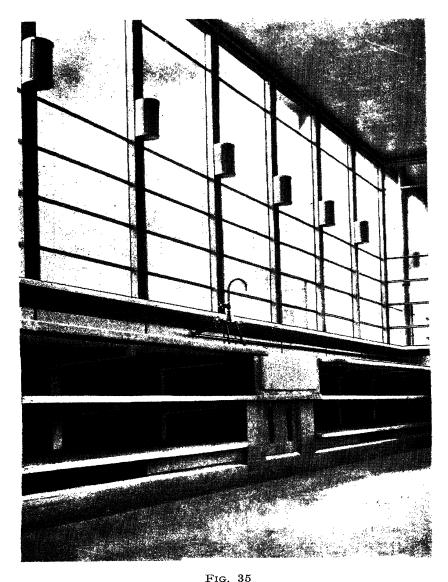
FIG. 34

A VIEW IN THE CHEMICAL LABORATORY OF THE DERBY RESEARCH LABORATORY OF THE L.M.S. RAILWAY. IT REVEALS THE UNIT PRINCIPLE: THE PERFORATIONS FOR BOLTING ON A PARTITION CAN BE CLEARLY SEEN IN THE GIRDER. THE GIRDER IN THE BRICKWORK MARKS THE BASE OF THE SERVICE DUCT

Courtesy of London, Midland & Scottish Railway Co., Ltd., and the " Industrial Chemist "

FIG. 35

CAST CONCRETE BENCHES DOWN SIDE OF LABORATORY SHOWING THE
ADEQUATE LIGHTING FROM THE OBSCURED GLAZING

Courtesy of Tunnel Portland Cement Co., Ltd., and the " Industrial Chemist "

the correct lines—it will quite often happen that a gang of operatives will be rendered idle unless the result is quickly available.   For such samples it is a good plan to make one assistant responsible for the work, and it will be his duty to report in writing to the supervisor in the factory that it will be in order, or otherwise, for him to proceed.   The records of this work, like all other analyses, will be card indexed, so that they can be referred to without delay.   Apart from the fact that it would be physically impossible for the chief chemist to scrutinise every analytical detail of all samples, there should be no necessity for him to do so provided the laboratory organisation is as it should be, and his staff reliable.   If, however, a batch of material turns out to be unsatisfactory, then it is obviously his duty to call for all the available analytical data, with the object of ascertaining where the fault lies.   These process samples should be retained until the batch they represent is completed, when they can be destroyed or re-examined as the case may be.

Finished Products

Important and useful work is to be done by the examination of the finished articles produced.   It must be ascertained that they are according to the standards laid down in the factory, that is to say, that they are what they are supposed to be.   It is very necessary to make as sure as possible that they are free from harmful substances, and that they strictly comply with the law governing the class of product to which they belong. Even in the factory, where every operation is under strict supervision, errors may and do occur, but their number can be reduced to a minimum by careful and systematic laboratory control.   A good plan is to draw samples haphazard from batches of finished goods at unstated times, so that the supervisor does not know when the articles for which he is responsible are to be sampled, and as a consequence he is careful to satisfy himself that those under his control are in their turn carrying out instructions.   It is also useful from time to time to draw samples of products in various stages of production so that a check can be maintained, step by step, from the commencement of manufacture to the completion. It will probably be found that it is seldom necessary to call attention to errors, but the fact that a watch is being kept has a very marked effect upon the efficiency of production.

Research

In large concerns with an enlightened directorate, a research depart-ment may be usefully incorporated as part of the technical staff.   The term " research " is not used here to imply work of fundamental nature,

such as that carried out in some of the universities. There is, however, another use of the word " research " by which it is inferred that scientific knowledge and experience are brought to bear upon some particular aspect of a manufacturing process ; this might more aptly be described as " technical research." It is almost, if not quite, impossible for the chemist in a canning factory to avoid this kind of work, for it is inseparable from the search for improvement in processes and the devising of new processes. Closely related to technical research are the problems of how existing products can be improved, without necessarily altering the processes of manufacture.

The chemist may, on occasion, be called upon to intervene between a dissatisfied customer and the sales department, in which cases he is expected to adopt the role of peace-maker. He will almost certainly be expected to interview public analysts and other Government officials, including Medical Officers of Health. He should therefore be tactful, and possess a very wide knowledge of his own subject, of Public Health Acts, etc.

A Card System

The details of any system must necessarily vary to some extent with the class of goods manufactured, and the number of members of the laboratory staff ; but it should be made an inflexible rule that every sample received must be properly recorded. A system which has been in operation for many years in one of our laboratories consists in drawing up a card to correspond to every sample received, the card bearing a consecutive number based upon the laboratory records. These cards are of sufficient size to allow the full analytical data to be written on them (all weighings, etc.), and in a space reserved for the purpose the result of the analysis is recorded. The sample to which the card corresponds is marked with the consecutive card number. The cards are placed in a suitable receptacle labelled " samples for analysis."

The assistant who is to conduct the examination takes the card from the rack or box, and retains it during the period he is engaged upon the analysis. If the work is not completed at the end of the day, the card is placed in a box in a rack marked " in course of analysis." When the examination is complete, the card passes to the rack marked " finished samples." These finished cards are then scrutinised by either the chief chemist or his first assistant, and if necessary a report is written, directed to the individual or department concerned. The card is then filed alphabetically, and can be referred to at any time. A book is also kept in which all samples are entered under the date upon which they are received, and this entry also bears the consecutive card number.

Where a report is made, it is filed preferably under a subject heading, and it also bears the card consecutive number.

An example is as follows :

SPECIMEN CARD

Water.   Boiler-feed, from No. 5 softening plant,   No. 507.
per Engineering Dept.

                                                          30/4/36.

(Here are the analytical details.)

Examination conducted by E. B.   Passed by W. S.

                                                  Reported by A. B.
                                                      to chief engineer.

                                                  (Filing details of
                                                          report.)

Retaining the Samples

A question often difficult to decide is, how long should samples be retained before destruction ?   Much depends upon the nature of the sample, and the ultimate destination of the article it represents. Obviously, therefore, no definite rule can be laid down, but unless storage space is unlimited, and a cold store for samples is available, they cannot be kept indefinitely.   A regular system of clearance is necessary ; certain samples can be thrown out weekly, others monthly, and so on.   The sample storage accommodation must be arranged so that the finished samples are grouped according to the length of time they are to be kept. No sample which is in course of analysis, or which has not been passed, should be placed in the sample storage department.   A sound plan is to· have a large cupboard, or cupboards, fitted with three shelves.   On the· top shelf are placed samples awaiting analysis ; on the second, samples in course of analysis ; and on the lowest, samples the analysis of which is. completed, but not scrutinised or reported.   When the sample cards have· been finally passed for filing, it should be the duty of one of the assistants to remove to the sample storage department the samples to which the cards refer.

Where many hundreds of analyses have to be made in the course of a few days, this method will be found of great value ; what is more, the position can be ascertained at a glance.

In regard to special analyses, these for the most part will arise in connection with trial processes or with attempted improvements in existing processes, and will probably be of interest only to the chemist. They therefore naturally fall into a somewhat different category from the routine samples, in comparison with which they will be very few in number.   A distinct card system should be adopted for this class of analysis, and may, if found desirable, be worked upon cards of a different colour.   They should come up for examination and comment as often as may be needed, so that the chief chemist may keep in touch with the progress made, and with any difficulties which arise.

The " technical research " department cannot be so satisfactorily conducted on a card system, for the work planned may extend to months before any tangible result is obtained, and more often than otherwise the plan has to be modified or entirely altered.   Such records are therefore best kept in book form by the research worker, who will from time to time present reports to the chief chemist, showing the progress made. It is, however, advisable to have a card made out under the " special analytical " card system, on which it is stated that a particular assistant began the work on a given date.   This card will constantly come before the chief as a reminder that the matter is in hand, and he can at any time call for a report, verbal or in writing, to find out what progress has been made.

It is only by adhering to a properly organised system that the chief chemist can have complete grasp of all the work under his control.

It is inadvisable to divide the laboratory staff into two distinct departments, analytical and research ; neither is it desirable to segregate the process-control men.   It quite often happens that the individual who has been in charge of a certain operation in a factory will, in the light of practical experience, make an excellent technical research worker.   The whole system should be made as elastic as possible, subject to close control.

In an efficiently conducted factory, all the technical operations should carry log sheets, and these should be forwarded to the laboratory at least daily.   As an example, the thermographs relating to the processing of canned goods must be the subject of careful scrutiny by a member of the laboratory staff, and any departure from the régime laid down must be followed up and an explanation obtained.

Close attention to all the small details of laboratory and factory technical operations will handsomely repay for the trouble expended. Experience has shown that the chemist should never have to say, " I do not know what happened."   If the whole of the work is carefully planned upon lines similar to those discussed, smooth running will result, and endless worries be avoided.

The Laboratory

The laboratory has to provide facilities for two kinds of work : routine analysis and technical investigation.   Although controversy places one or the other first, according to idiosyncrasy, no doubt should be entertained that the canning laboratory must be organised and laid out to handle routine analysis expeditiously and accurately.   Many tens of thousands of samples will have to be dealt with every year.

Happy is the chemist who has the opportunity to design his own laboratory building.   The general run have to adapt and equip existing buildings or parts of them.   Even so, there are certain general principles

Fig. 34

A VIEW IN THE CHEMICAL LABORATORY OF THE DERBY RESEARCH LABORATORY OF THE L.M.S. RAILWAY. IT REVEALS THE UNIT PRINCIPLE: THE PERFORATIONS FOR BOLTING ON A PARTITION CAN BE CLEARLY SEEN IN THE GIRDER. THE GIRDER IN THE BRICKWORK MARKS THE BASE OF THE SERVICE DUCT

Courtesy of London, Midland & Scottish Railway Co., Ltd., and the "Industrial Chemist"

that must be adhered to if the laboratory is to function efficiently and give the factory the service it requires.

It must be situated away from dirt and dust. It should therefore be as far as possible from the boiler house and the delivery and dispatch of raw materials and finished products. The wise chemist will see that it is to the windward (according to the prevailing wind) of these parts of the factory and any other part likely to pollute the atmosphere. It should be as far from heavy machinery as possible, vibration being anathema in the balance room : this will also ensure its staff working in quiet. At the same time it should be as close to the administrative offices as possible: for obvious reasons the chemist needs to be in close touch with the rest of the executive staff.

Lighting is very important for accurate scientific work. Not only should the laboratory accommodation receive the maximum possible, but the rooms and working areas in them should be arranged to receive maximum illumination. Windows should be located so that they give the fullest light on the benches at working level. Direct sunlight should be avoided, or if this is impossible, windows should be glazed with a hammered or other glass that will diffuse the light. Roof lights are to be avoided not only for this reason but for another, that they act as unpleasant moisture condensers in cold weather.

Separate Rooms

Laboratory accommodation must permit of a number of separate rooms. There must be a sample receiving room where clerks can enter up details, and make out the cards, etc., and with sufficient cupboard accommodation for sample storage ; alternatively there must be a sample store in addition. There must be a library for records, technical books and journals, and accommodation for the chemist and his staff to work. A separate balance room is essential : alternatively, small balance rooms may be partitioned off the appropriate laboratory. The balance room, or rooms, must be absolutely free from vibration and corrosive atmospheres and must be well lit. It should be fitted with softly closing doors and they should be shut at all times. In the food canning laboratory a room for polarimeters and other optical equipment is essential. There should also be a room for glass-blowing and similar operations in the making of apparatus. A store-room for reagents and apparatus is needed. In the canning laboratory separate rooms for bacteriological work are needed and they should be designed so that the atmosphere in them is kept as still as possible and free from dust. It is a good plan to provide them with a small ante-room. Finally, the chief chemist must have his office or office-cum-laboratory where he can interview the numerous callers that so obligingly consume his valuable time, and from which he can control

the work in laboratory and factory, and in which he can at the same time enjoy a little privacy.
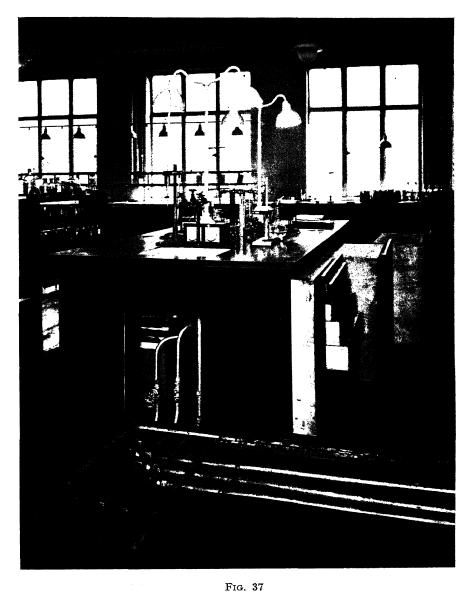
Other than these essential rooms, the accommodation may be divided into as many or as few rooms as is possible or desirable. Some prefer the latter. In the laboratory at the newly built Glaxo Laboratories, for example, the laboratory is one large room organised on the " bay " system. The benches are arranged on each side of a central gangway in bays to which work of the same kind is kept. It gives an atmosphere of freedom and spaciousness conducive to good workmanship. On the other hand it is not always possible to arrange the work except in separate rooms. Whichever scheme is adopted, rooms or bays must be so arranged that samples flow from one to the other expeditiously, and either back to the sample store, or to the sample-store-cum-sample receiving room. And the sample cards flow with them in an efficient manner.

The Layout

Sound foundations of the laboratory building are necessary to safeguard against vibration. Their nature must of course vary with the site and nature of the soil and they are rather the architect's concern than the chemist's. The walls may be of brick or, if the building be of steel structure, may be of any other suitable material. Single- or multi-storey design may be adopted : if the latter, the balance and optical rooms should be on the ground floor. To-day there seems to be a desire to design the building with a central corridor running from end to end, or, alternatively to arrange the separate rooms on each side of a central corridor, which then ends in the one large laboratory occupying the whole width of the building. The reason is not far to seek. The services may be led down the centre of the building either below the floor or overhead below the ceiling and the floor of the upper storey. From this central channel leads may be taken off at will into the various rooms, or, in the case of one large room, to the various benches. Drainage is usually provided for on the outer walls.

Increasing favour is being shown for internal construction to be of the unit type. That is to say, the superficial area between central corridor and outer wall is divided into equal areas, equal to the smallest convenient laboratory dimensions. The steel framework is arranged to coincide with these dividing lines and so constructed that steel frame partitions may be bolted to it. This renders the building exceedingly adaptable, as the partitions between rooms may be removed and the rooms made into one, two, three or more " units." An example of such construction is the Research Laboratory of the London Midland and Scottish Railway at Derby.

The interior decoration of the walls should be such as to give the maximum of pleasant work light. Some prefer white enamel, but this is

FIG. 37

ANOTHER BENCH IN THE LYONS' LABORATORIES SHOWING THE DRAWER AND CUPBOARD SECTIONS AND THE PANELS COVERING THE SERVICES REMOVED

Courtesy of J. Lyons & Co., Ltd., and the " Industrial Chemist "

Fig. 38

UNIQUE FUME CUPBOARD IN LABORATORY OF THE TUNNEL PORTLAND CEMENT CO., LTD.

Courtesy of Tunnel Portland Cement Co., Ltd., and the "Industrial Chemist"

inclined to be too glaring. In the L.M.S. Railway laboratory up to waist level the colour is an elephant grey divided from an upper colour of pale green by a narrow black band. In designing the research laboratories at the Hendon works of Kodak, Ltd., the results of a special study of the problem were applied, and the walls are finished in matte-cream-broken white enamel. The walls of the laboratories in Hammersmith Road, London, of J. Lyons & Co., are finished in a white cellulose enamel. Lead paints should be avoided owing to their tendency to darken in the usual laboratory atmosphere. White tiles have their devotees.

Flooring needs careful consideration. In the canning laboratory it must be fat and acid resistant. The ideal floor has yet to be found. Some pin their faith in tiles where acids and fats are liable to be spilt, and where this occurs constantly they probably cannot be equalled. But they are uncomfortable to work on. With proper care the newer asphaltic or magnesite types of cements will give sufficiently good service. These have the advantage of comfort combined with an easiness of cleaning. When properly laid they are jointless and are moulded at the wall base to avoid the dust-collecting angle. Then they can be quickly washed down with water and a squeegee. Dressing preparations are obtainable which improve their water-resistant properties. Wood block floors are also in general favour and a good beeswax polish, provided it is applied once a week or so, will take care of most spillings short of a major catastrophe such as a broken Winchester of acid, and that of course must be cleared up at once from any floor.

Services

The chemist must decide for himself what services he requires. Power for lighting, for small motors, driving, stirring and other devices, and for heating is essential. Some laboratories are equipped with both A.C. and D.C., and some with various voltages. Town's gas is likewise essential : there are some things that can only be done with a Bunsen. Water is another essential : some laboratories are provided with both hot and cold. Steam is another valuable service usually obtainable in a works laboratory : and when it is available, power heating may be dispensed with. Compressed air has its uses but is somewhat of a luxury. A vacuum line is useful and, when the water pressure is variable, as it frequently is in a factory where sudden calls may be made on it, it is absolutely essential for the steady working of suction filters on the benches. Other services may be added as desired, such as clock cables and conditioned air. Pipes and leads should be painted in distinguishing colours.

Benches should be of convenient working height, usually three feet or three feet three inches from the floor. In the modern laboratory they are arranged along the outer wall where the maximum light is obtainable

and where they are convenient for drainage purposes. The favourite bench top is teak impregnated with beeswax : a weekly clean down with a wax in turpentine preparation keeps them in excellent condition. Where much acid is used a deal top covered with sheet chemical lead has its advantages. There are some chemists who like an asbestos cement top and in one laboratory at least, that of the Tunnel Portland Cement Co., Ltd., at West Thurrock, Essex, the tops are of pre-cast concrete slabs covered with rubber sheeting.

To-day the tendency is for benches to be fixed, and some ingenuity has been displayed in making the services accessible. In the Lyons' laboratory, for example, the drawers and cupboards are built in units upon castors so that they can be rolled away from under the bench. This is a more expensive method than at the L.M.S. laboratory, where only those sections immediately in front of the sink services are removable. In some laboratories the sink area is covered by a plain panel. The cheapest way is to leave the sink space clear of cupboards and drawers. The reduction in accommodation is comparatively little and need not be unsightly. The more modern bench is designed with ample " toe " room at the floor by leaving space below the cupboards or by setting both cupboards and drawers sufficiently far back, and letting the bench top overhang by six to nine inches. Extension devices similar to those on filing cabinets not only cancel the overhang but permit fuller examination of the contents of the drawer than is possible in the normal drawer. This scheme has been installed in the new tobacco laboratories of the Government Laboratory, Clement's Inn, London.

To-day sinks are not distributed all over the laboratory, but kept to the bench ends on the outer wall. Where condenser discharge is wanted, an open trough is provided at the back of the bench, connecting to the sink. The hole in the bench leading to a drain is out of favour as being difficult of access and complicating the bench system. The bench top is continuous and an opening cut in it a little smaller than the sink, which is wedged firmly against it from below. If the front of the bench is left open at the sink the latter is removable when necessary without much disturbance. Furthermore the drains are accessible. The sink should discharge into a glazed earthenware dilution chamber below it before the discharge passes to the drains, which also should be of glazed earthenware. The uses of the dilution chamber are obvious. The drains, with an adequate fall, are arranged to run the length of each outer wall under the windows, connecting all the sinks to the main drainage system.

Care should be bestowed upon the fume cupboard. In too many laboratories it is nobody's care and becomes the depository of dirty un- wanted apparatus. Special attention should be given to the maintenance of its ventilation : after all its function is to segregate and get rid of corrosive fumes. The bench should be of slate or tiles and the walls

tiled. The vents should be earthenware and the fans made of acid resistant metal or earthenware. The draught should be controllable at will. At the Tunnel Portland Cement Co.'s works, what may be termed a de-luxe fume cupboard occupies the centre of the chemical laboratory. This is a hexagonal glass and concrete structure divided by glass partitions into six compartments. The fumes are drawn into a central hollow column and the draught in each compartment is controlled by a glass damper on the central column. At the Lyons' laboratories a system of flues connects all cupboards to the fans housed on the roof. Besides fume cupboards proper, there may be individual benches that need hooding and connecting to a fume flue, such as the Kjeldahl bench. The chemist must decide for himself how many benches must be protected in this way for expeditious working.

Only the principles of laboratory organisation and the essential design have been outlined here. The chemist will easily fill in the gaps for himself, knowing the type of work he wishes to undertake. We have not attempted to describe special equipment that may be needed, that is made clear in later chapters. In the bacteriological laboratories adequate incubating and sterilising apparatus is essential for good work. Wherever colour matching, as in titration or comparison of samples, is undertaken, it is advisable to have good and constant lamps of the " daylight " type. Distilled water is another essential service and the chemist will be well aware that it should be made as freshly as possible: prolonged storage except in costly vessels means its loss of its needed purity. The still or stills selected should be of sufficient capacity to provide water for efficient working of the laboratory.

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CHAPTER V

EXAMINATION OF RAW FOODSTUFFS

THE raw materials used by the canner must obviously reach certain standards of quality. Whilst the foods themselves are usually judged by well-known market standards and the canner's experience of what will, and what will not, can satisfactorily, such ways of estimation are difficult of codification except in so far as in grading for size and colour in the example of fruit, vegetables and some fish. So far as is possible these have been described in Chapter II. There are, however, certain properties that can be examined chemically such as the fat of milk, the sucrose of sugar and the fibre in cereals. On the other hand, there are definite constituents and impurities that must be looked for. In this chapter are given briefly the majority of the chemical tests the canner may want or need to apply. For others he is referred to the standard analytical textbooks.

Cereals

A determination of the moisture, ash, protein and crude fibre will probably give all the information that is needed in the case of cereals used in the canning factory, although more data will be required where the manufacture of baked cereal products, such as bread, and so forth is undertaken.

Arsenic. It is desirable with all cereals to make a search for arsenic, and if the amount found exceeds a minute trace, steps should be taken to trace its origin.

Sulphur Dioxide. Certain of the cereal products, such as cornflour (maize starch) and other prepared starches, are permitted under United Kingdom regulations to contain sulphur dioxide as a preservative to an amount not exceeding 100 parts per million, and therefore this substance must be sought for, and if present the amount determined.

Ash. Incinerate 2 grammes of the substance in a platinum dish at dull red heat, preferably in a muffle furnace at low temperature. The application of heat should be maintained until the residue is white or only light grey in colour. Too high a temperature must not be employed, otherwise some volatilisation of potassium and sodium salts may occur.

70

Moisture. 5 grammes of the substance should be dried in a vacuum drying oven at a temperature not exceeding 90° C., until the weight is constant.

Protein. This is determined by the Kjeldahl Gunning method described on page 134.

Crude Fibre. For particulars of the determination of this substance the reader is referred to page 136.

Details of the composition of the various cereals are to be found in *Modern Cereal Chemistry*, Kent-Jones.

The above determinations should be followed by a microscopical examination by means of which cereal adulterants can be detected. The reader is referred to Greenish and Collin's *Anatomical Atlas of Vegetable Powders*.

Sulphur Dioxide in Foods

The method of Monier Williams[1] may be regarded as that most usually employed by public analysts, but for routine laboratory work the following method saves much time and gives results which in accuracy are fully comparable with the Monier-Williams method.

It was devised by a special committee of the Manufacturing Confectioners' Alliance and of the Food Manufacturers' Association,[2] of which committee one of the authors was a member. It is applicable to practically all kinds of foods, with some modifications for particular substances such as cereals.

A uniform sample having been prepared, it is treated in the following manner. Where much sulphur dioxide is not expected to be present, 100 grammes of the sample is a desirable quantity upon which to work.

The weighed quantity is introduced into a round bottomed flask of 500 c.c. capacity (when 100 grammes of the sample is used, the flask should be of 1,000 c.c. capacity). The flask is fitted with a rubber stopper carrying two holes, and should have been previously well boiled in water to free it from sulphur dioxide.

Fitted to the flask is a dropping funnel and a still-head of special design. This consists of two bulbs, each approximately $1\frac{1}{2}$ inches in diameter, blown close together, with a restriction of about $\frac{7}{8}$ inch between them. The tube below the bulbs, passing through the rubber stopper into the flask, is $\frac{1}{2}$ inch in diameter, and about 4 inches long, the end being cut off obliquely. There is a hole about $\frac{1}{8}$ inch in diameter at a distance of 1 inch from the bottom tip of the tube. The tube above the bulbs is $\frac{1}{4}$ inch in internal diameter, and is bent at right angles just above the upper bulb, and again bent at right angles, leaving about 6 inches between the first and second bend, so as to fit to an upright Liebig condenser. The condenser should be not less than 18 inches long, and the inner tube $\frac{1}{2}$ inch in diameter. At the lower end of the condenser there

is fitted an adapter of special type. It consists of an upper cylindrical portion by means of which it is fitted to the condenser, the joint being made with a rubber bung. This portion is about 1 inch in diameter and 3 inches long. It is constricted to a diameter of $\frac{1}{4}$ inch, and is about 4 inches long. At the lower end, the tube is opened out into a bell-shaped portion, about $1\frac{1}{2}$ inches long and 1 inch in diameter, in which there are two holes opposite to each other. This bell-shaped portion is covered with a similar shaped device of somewhat larger diameter, and fitted with two holes at right angles to the two holes in the inner bell. This device is needed efficiently to scrub the rapidly emerging gas. Both the still-head and the special adapter can be obtained from any reputable laboratory apparatus manufacturer.

Freshly boiled water (boiling to be continued until the water is completely de-aerated) must be used in the distillation flask.

Sufficient distilled water is placed in a large receiving beaker completely to cover the outer bell of the adapter. To this is added about 0·5 c.c. starch solution, and a few drops of N/20 iodine, the volume used being noted.

Four hundred c.cs. of the de-aerated water are placed upon the sample under examination in the distilling flask, followed by 100 c.cs. of concentrated hydrochloric acid (for cereals and gelatine), which is placed in the dropping funnel attached to the distillation flask. All the acid is run in, and the flask at once heated with a large burner, without the intervention of a gauze. Boiling should take place in, at most, $2\frac{1}{2}$ minutes from the time that the acid has been added. As the distillation proceeds, N/20 iodine solution is added from a burette to the receiving beaker so as just to maintain a blue colour. Much of the sulphur dioxide gas distils over in the first few minutes, and in nearly all cases the reaction is complete within ten minutes. It should be continued until 0·1 c.c. of the standard iodine solution causes the blue colour to persist for two minutes. Unduly prolonged boiling may produce reducing substances other than sulphur dioxide. If it is found that the gas has not been completely removed in ten minutes, then recourse should be made to steam distillation.

One c.c. of N/20 iodine is equivalent to ·0016 grammes of SO_2.

Full details of the method are to be found in the *Analyst*.[2]

The whole operation can be comfortably carried out in 15 minutes, from start to finish, and will give results which in accuracy compare favourably with any other methods, provided that the technique described is followed exactly. The length of time employed in bringing the contents of the flask to boiling point is of great importance. A delay at that stage leads to oxidation of the sulphur dioxide and a consequent low result.

Note.—For substances other than starches and gelatine, 25 c.cs. of a 20 per cent. solution of phosphoric acid is recommended in place of the 100 c.cs. of concentrated hydrochloric acid used in the distillation flask.

The employment of hydrochloric acid is needed to prevent gelatinisation of the starch.   It will also prevent the gelatine from sticking to the bottom of the flask and causing it to fracture.

Gelatine

This substance is of more interest to meat canners than to those who handle fruit and vegetables.   The chief points of importance in connection with canning are :

(1) The strength of the jelly produced after, as well as before, processing.

(2) The clarity and colour of the jelly.

(3) The percentage of total calcium salts, as these have a bearing upon the clarity of the jelly.

(4) The amount of sulphur dioxide.

(5) The arsenic present, and the amount.

Jelly Strength. Prolonged heating of gelatine gels, particularly in the presence of sodium chloride, leads to hydrolysis and consequent loss of jelly strength.   As the canner of meat almost invariably has to deal with meat containing some salt, and to carry the processing temperature above 100° C., gelatines must be tested to select those which suffer the least deterioration as the result of the treatment they are subjected to.

The accurate determination of jelly strength involves the use of complicated apparatus, particularly where the results obtained are needed to bear strict comparison with determinations made in another laboratory.   For details of the apparatus, the reader is referred to "The Standard Methods (Revised) for Determining Jelly Strengths of Glues and Gelatines."[3]   For the majority of purposes what is known as " the finger test " is surprisingly accurate and will suffice to differentiate between various samples, or, if preferred, the simple jelly testing device of C. R. Smith[4] may be used.   This consists of an 80 mm. short-stemmed funnel accurately formed at an angle of 60°, closed at one end ; 120 grammes of mercury are poured in, forming an upper surface 3 cm. in diameter.   Over the mercury is layered 50 c.cs. of gelatine solution which is allowed to set in a horizontal position (fixed by spirit level) in a constant temperature bath at 10° C.   The mercury is then run out, the funnel connected with a water manometer, and a reduction of pressure (6 dm. of water) is produced.   The depression of the upper surface of the jelly, produced by the suction, is measured with a micrometer, and the jelly strength thus determined.

The details of the preparation of the samples for the strength test are as follows :

Strength of Unprocessed Jelly.   2·5 grammes of the finely divided sample are dissolved in about 50 c.cs. of hot water in a beaker of 150 c.cs. capacity.   Solution is brought about by heating the beaker upon the

steam bath, and stirring with a glass rod. When the whole of the gelatine has passed into solution it is cooled and the volume of the solution made up to 100 c.cs. The standard with which the comparison is to be made is treated in an exactly similar manner. Both beakers are then allowed to cool for some hours at a temperature of 10° C., and the strength test then carried out. If the test is to be made at a temperature higher than 10° C. a stronger solution of the gelatine and standard should be made.

Strength of Processed Jelly. A sufficient volume to fill a 1 lb. can, of a 5 per cent. solution of gelatine in $2\frac{1}{2}$ per cent. sodium chloride solution is made, the can filled, sealed and then processed for the desired time at a pre-determined temperature. The can is cooled to atmospheric temperature as rapidly as possible, and then kept at a temperature of 10° C. for some hours. At the end of this period it is opened and the strength of the jelly compared with that produced by the standard treated under precisely similar conditions.

The Clarity of Gelatine Solutions. This is of considerable importance, for it very materially affects the appearance of those articles in which it is employed.

One of the most accurate instruments available for the purpose is that designed by the Imperial Chemical Industries, Ltd., a description of which is as follows. The authorised makers of the instrument are Messrs. Baird and Tatlock, Ltd. :

The I.C.I., Ltd., Gelatine Clarity Tester. This instrument is designed primarily to measure the clarity of gelatine solutions, so that some precision may be given to an important characteristic upon which value to some extent is based. The grading in clarity recorded by the instrument corresponds with that of a visual examination. The instrument may also be used to measure the clarity of other aqueous solutions.

Clarity is defined for this purpose as the percentage of light transmitted by the solution compared with that transmitted by distilled water measured under the same conditions. The solutions to be tested are contained in 2-in. glass-ended troughs such as are used for colour measurement in the Lovibond Tintometer. The troughs are placed in the path of a parallel beam of light (from a tungsten filament) suitably stopped to minimise reflection from the walls of the vessel and from the meniscus of the liquid. The light transmitted is received on the sensitive face of a photo-electric cell and is measured by a micro-ammeter, the reading on which for distilled water is adjusted to the value 100 m.a. by varying the lamp resistance (a coarse adjustment) or the galvanometer shunt resistance (a fine adjustment). When the trough containing the solution to be examined is substituted for that containing the distilled water, the reading given by the ammeter records directly the defined clarity ratio.

This clarity ratio is independent of quite large vibrations in the in-

tensity of the light source, and infra-red rays from the light source are without appreciable effect, since they are absorbed in both distilled water and the aqueous solution.

The light should be switched on four or five minutes before measurements are taken, to enable the photo-electric cell to settle down to a steady state.

Care should be taken to see that the trough and the glass ends of the troughs used are perfectly clean. Immediately before the testing of every sample solution, the distilled water reading should be taken and adjusted if necessary to the value 100.

If the sample is a gelatine solution, note should be made when the clarity measurement is made in the gel or sol form. If the former, definite ageing conditions should be adhered to, e.g., two hours at 20° C. In general, the clarity ratio varies little with temperature, except in the case of dilute solutions (up to about 6 to 7 per cent.) in the isoelectric range p_H 4 to 6. In this region the clarity ratio is less.

Colour of Gelatine Solutions. Gelatines are frequently found to show a considerable variation in colour, in general the cheaper grades possess a deeper tint than the more highly refined. It is a matter of no difficulty to judge visually between the various tints.

Iron in Gelatine. The amount of iron present in the gelatine has an important bearing upon the colour of the solution ; it produces a green tint, and bearing in mind the deleterious effect of iron in the presence of sulphur compounds, such as the proteins of meat, only those grades which contain a minimum of iron, not exceeding 4 to 5 parts per million should be used. For this reason every batch of gelatine should be examined for iron and its amount determined. Ten grammes of the sample are completely incinerated in a silica or platinum basin, the ash moistened with concentrated hydrochloric acid, and evaporated to dryness on the sand bath. About 20 c.cs. of dilute hydrochloric acid are then added, and raised to boiling-point. The solution is then filtered, the contents of the dish being well washed with hot water. The filtrate and washings, if the volume exceeds 50 c.cs., are reduced by evaporation, two or three drops of nitric acid added, boiled, and the volume made up to 50 c.cs. It is then transferred to a Nessler tube, and the iron determined in it by the colorimetric method described under water analysis in Chapter VII.

Calcium in Gelatine. The presence of calcium salts in the gelatine are the frequent cause of the formation of a cloudy jelly, unless the p_H of the solution is kept at about 4·5. This is not always practicable, and it is therefore preferable to work with gelatines the total calcium content of which, expressed as lime, does not exceed 0·2 per cent.

Ten grammes of the finely divided sample are weighed into a tared platinum basin and incinerated in the muffle furnace. The residue is weighed and constitutes the total mineral content of the sample. The

residue is treated with about 5 c.cs. of concentrated hydrochloric acid, and evaporated to dryness on a hot plate or sand bath. This process is repeated in order to render all the silica insoluble. The residue is then taken up in hot dilute hydrochloric acid and transferred to a beaker of about 400 c.c. capacity. Sufficient ferric chloride solution is added to precipitate all the phosphate, followed by just sufficient dilute ammonia to start precipitating the ferric hydroxide. Dilute hydrochloric acid is now added drop by drop, until the precipitate dissolves with difficulty. Care must be taken to avoid any undue excess of acid at this point. Solid sodium acetate is now added to precipitate completely all the iron salts as basic ferric acetate, coagulation of the precipitate being assisted by vigorous boiling. The precipitate is filtered off at the pump, being thoroughly washed with hot water. The filtrate, which should be quite colourless, is rendered alkaline with ammonia solution and sufficient of a saturated solution of ammonium oxalate added to precipitate all the calcium. The solution is boiled, allowed to stand until the precipitate has settled, after which it is collected upon a filter paper, and washed with hot water until the washings show no opalescence with calcium chloride solution. The precipitate is now completely transferred to a beaker, dissolved in dilute sulphuric acid, the solution heated to 60°C., and, whilst hot, titrated with tenth-normal potassium permanganate solution until a permanent pink colour is produced.

One c.c. of deci-normal potassium permanganate is equivalent to 0·0028 grammes of CaO.

Arsenic. This is tested for by the Gutzeit Method, details of which are given on page 148.

If it is desired to determine copper and lead in the gelatine, the method described for the detection and determination of these two metals in canned food will apply equally well to gelatine.

Salt in Pickling and other Brines. A definite volume of a suitable dilution of the brine is titrated with tenth-normal silver nitrate solution, in the usual manner, using potassium chromate solution as an indicator.

One c.c. of N/10 silver nitrate solution is equivalent to 0·00585 grammes of sodium chloride.

In the case of brines containing 15 to 30 per cent. salt, a convenient dilution is 20 c.cs. of the original brine, made up to 250 c.cs. with water, and 50 c.cs. of the dilution taken for the titration.

A deci-normal solution of silver nitrate contains 16·989 grammes per litre.

Nitrates and Nitrites in Meat Products

The accurate determination of nitrates and nitrites in meat and meat products, as well as in pickling brines, has always presented a difficult

problem to the analyst, and until quite recently no really satisfactory method had been evolved. All the existing methods possessed one or more features which interfered with the correctness of the results.

Allen's *Commercial Organic Analysis,* and other works dealing with the subject, recommend the Schlösing-Wagner method, which depends upon measuring the volume of nitric oxide generated by the action of a nitrate upon ferrous chloride in the presence of hydrochloric acid. For details of the *modus operandi* the reader is referred to Allen's *Commercial Organic Analysis.*[5] The disadvantages of the method are that it is difficult and messy to operate on account of having to manipulate gas burettes partially immersed in hot strong caustic soda solution, and also because in many cases the volume of gas evolved from the meat is so small as to render inaccurate the calculations based upon it. If a large amount of the meat, say 100 gms., is employed, then the quantity of fat and other organic matter interferes with the satisfactory extraction of the sample with hot water. The difficulties are minimised when working with pickle, but even then the results obtained, working with known strengths of nitrate, leave much to be desired.

The method in which the nitrate is converted into ammonium picrate and estimated colorimetrically is also inaccurate. It depends upon the formation of picric acid by the action of phenol-sulphonic acid and sulphuric acid upon a nitrate, and then by the addition of ammonia, ammonium picrate is produced, which is compared colorimetrically against a standard solution. The difficulty that arises here is that the soluble protein matter extracted along with the nitrate from the meat is charred by the action of the sulphuric acid, and renders it impossible to place any reliance upon the matching up of the colour of the unknown with the standard. Various methods for the removal of the soluble protein matter have been tried, but all of them interfere with the final colour of the ammonium picrate solution.

Attempts to reduce the nitrate to ammonia, by the use of zinc-copper couple or Devada's Alloy, have shown that great errors are introduced because part of the protein nitrogen also becomes converted to ammonia. This method is quite hopeless.

J. Blom and C. Treschow[6] devised a method for the determination of small quantities of nitrates in soils and plants, based upon the formation of 5-nitro-*m*-4-xylenol, and its subsequent distillation in steam, and colorimetric determination after rendering alkaline with sodium hydroxide. Organic matter in the sample is removed by heating with sulphuric acid and permanganate. According to the authors, no loss of nitrate occurs during this process and there is no appreciable oxidation of ammonia or of amino-acid to nitrate. Excess of permanganate may be removed by oxalic acid prior to the addition of the xylenol. Continued trials with this method for the determination of nitrate in meats and pickles have shown inaccurate results, which are apparently due to some loss of nitrate during

the removal of the organic matter, and in other cases to the oxidation of ammonia to nitrate.

McVey's Method. This method[7] has been tried out on many samples of cured meats, meat products, such as brawn, and new and used pickle, and it has been found to give excellent results, and is probably by far the best of the existing published methods.

The figures obtained, working with known strengths, have been found to be accurate within ± 5 parts per million.

The method of W. C. McVey is a modification of Blom and Treschow's method, and is carried out as follows :

Solutions required :

(*a*) Sulphuric acid (1 in 10).

(*b*) Sulphuric acid (3 in 1).

(*c*) *Meta*-xylenol (1 per cent. soln.).

(*d*) Silver ammonium hydroxide. Dissolve 5 gms. pure silver sulphate in 60 c.cs. ammonium hydroxide, heat to boiling, concentrate to 30 c.cs., dilute to 100 c.cs. with water.

(*e*) Potassium permanganate solution. Approx. 0·2 N.

(*f*) Phospho-tungstic acid, 20 per cent. solution.

(*g*) Sodium hydroxide solution, 10 gms. per litre.

(*h*) Bromocresol green indicator.

(*i*) Standard solution of nitric acid, 0·0375 N. (1 c.c. = 0·5 mgs. nitrate nitrogen).

Method. Weigh into a 150 c.c. beaker 5 to 10 gms. of the finely minced sample, add 80 c.cs. of water and warm on a steam bath for one hour ; break up any lumps with a glass rod. Transfer to a 100 c.c. flask, cool, make up volume and thoroughly mix. Filter or allow to settle, and take 40 c.cs. of the filtrate and place in a 50 c.c. flask. Add three drops of bromocresol green indicator and acidify carefully with dilute sulphuric acid (*a*) until colour just changes to yellow. Add potassium permanganate solution (*e*), to oxidise nitrites to nitrates, drop by drop until a faint pink colour is produced which persists for one minute. Add 1 c.c. of dilute sulphuric acid (*a*) and 1 c.c. of phospho-tungstic acid solution (*f*). Make up to the mark and filter.

Into a 300 c.c. conical flask place an aliquot of the filtrate, containing approximately 0·15 to 0·25 mgs. of the amount of nitrate it is expected to find. Volume of filtrate used should not exceed 15 to 20 c.cs. Add sufficient silver ammonium hydroxide solution (*d*) to throw down both chlorides and excess of phospho-tungstic acid. (A slight excess of this reagent is not harmful.) To the flask containing the extract and the precipitate, add three volumes of the strong sulphuric acid (*b*), stopper, mix and cool to 35° C., add three drops of *m*-xylenol (*c*). Shake well and hold at 30° to 40° C. for 30 minutes. In the presence of nitrates, a yellow to brownish-yellow colour develops. A bright red precipitate indicates

the presence of unprecipitated phospho-tungstic acid. This should be ignored. Dilute the mixture with 100 c.cs. of water and distil 40 to 50 c.cs. into a receiver containing 5 c.cs. of the dilute sodium hydroxide (g). The nitro-xylenol distils readily in steam and forms a brilliant yellow to orange-red colour in alkaline solution. Transfer distillate to a Nessler tube and make up to volume.

Into another 300 c.c. conical flask measure 1 c.c. of the standard nitric acid solution (i). Add 4 c.cs. of water and 15 c.cs. of strong sulphuric acid (b), cool and carry out the nitration and distillation as described above. Make up distillate to 500 c.cs., and, using Nessler glasses, make up a series of standard tubes.

Nitrite

It is sometimes desired to determine the nitrite separately and although there are other methods the authors prefer that given below.

For the determination of nitrite the best method at present is that known as the Griess-Ilosvay method. It depends upon the formation of an azo dye by the interaction of sulphanilic acid, alpha-naphthylamine and the nitrite, and the subsequent colour comparison of the tint produced with a solution of nitrite of known strength. The figure obtained should be calculated as nitrate and deducted from the total nitrate found when analysing for that substance ; the net figure thus arrived at will be the true amount of nitrate in the sample.

Nitrite in Meat and Pickling Brines

(a) *In meat.* 50 to 100 grammes of the sample are boiled with successive quantities of water, which are passed through a wet filter paper (this will retain the fat). The extract is concentrated to a bulk of 100 c.cs. and 50 c.cs. of it are treated in the manner described as under.

(b) *In pickles.* 10 c.cs. of the pickle are placed in a 500 c.c. graduated flask, diluted with 250 c.cs. of water, which must be free from nitrite, and if coloured red, dilute acetic acid is added until the colour is discharged. The volume is then made up to the mark and 50 c.cs. measured into a Nessler tube. To these are added 2 c.cs. of each of the following solutions :

(1) 1 gramme of sulphanilic acid is dissolved in 15 grammes of glacial acetic acid, to which about the same volume of water is added. When solution has been effected, dilute the solution to 315 c.cs.

(2) 0·2 gramme of a-naphthylamine is dissolved by heat in 60 grammes glacial acetic acid, and after solution has taken place the volume is diluted to 350 c.cs. with distilled water.

The pink colour produced is matched against a known volume of standard sodium nitrite solution, the maximum density of colour being

reached in 15 minutes. The intensity of the colour is increased in the presence of sodium chloride, therefore an amount of this salt equivalent to that found in the meat, or brine, should be dissolved in the dilution of the standard reagent in the Nessler glass. Very dilute sodium nitrite solution is liable to become weak, it is therefore advisable to make a stock solution containing 10 grammes per litre, and dilute this as needed to 0·01 grammes sodium nitrite per 100 c.cs. of water.

Determination of Sugar in Pickles

Ten c.cs. of the brine (or less, if more than 2·5 per cent. of sugar is expected) are heated with an excess of dilute hydrochloric acid for a period of ten minutes in order to invert the sugar. To this mixture is added an excess of Fehling's solution, and the vessel heated in a steam-hole for ten minutes. The cuprous oxide produced is filtered off on to a tared filter, thoroughly washed, dried in the oven and weighed as cuprous oxide. From the weight found, the quantity of sugar present in the brine or pickle is calculated.

One gramme of cuprous oxide is equivalent to 0·4308 grammes of sucrose.

Fehling's solution : (1) Dissolve 69·28 grammes pure copper sulphate in 1,000 c.cs. of water.

(2) Dissolve 350 grammes Rochelle salt and 100 grammes sodium hydroxide in 1,000 c.cs. of water.

For use mix 25 c.cs. of (1) and of (2) together.

It is advisable to keep the two solutions separate, if kept mixed chemical change and consequent alteration in strength gradually takes place.

When a used pickle is being examined, it is necessary to remove the dissolved protein matter before proceeding to the addition of the Fehling's solution. This can be brought about by the use of a protein precipitant and phospho-tungstic acid will be found suitable.

To 10 c.cs. of the sample, add just sufficient dilute hydrochloric acid to render the solution acid, and then 5 to 10 c.cs. of a 2 per cent. solution of phospho-tungstic acid containing sulphuric acid. Shake thoroughly and allow to stand for one hour. Filter off the precipitate, wash thoroughly with water and proceed to determine the sugar in the filtrate by the method above described.

Determination of Sugar in Peas

The peas are weighed, crushed and treated with 95 per cent. alcohol in Soxhlet extractors until all the sugars have been removed. The extract is concentrated under reduced pressure, the sugars inverted with acid, and the total sugars determined by the methylene blue method of Lane and Eynon,[8] described later in this chapter, or by the same gravimetric method given under the determination of sugar in pickles.

Sugar

It is generally considered that the preservative property of the sugar syrup used in canning fruit, sweetened milk and so forth, depends upon its sucrose content. Sugars may be purchased according to specification, but even so it is advisable for the canner to have methods whereby he can test their purity. The growth of micro-organisms in canned foodstuffs preserved in syrup would appear to be promoted by the presence of invert sugar and protein, therefore these should be kept as low as possible. Another possible impurity is sulphur dioxide in the form of sulphites, and this is objectionable for two reasons, one being that sulphur dioxide ranks as a preservative, and therefore there may be legal reasons for its exclusion, and secondly, because of the possible blackening effect of the sulphur dioxide upon the tinplate. Bacterial contamination is also more than possible except with highly refined sugars of over 99·5 per cent. of sucrose. As pointed out in other chapters, sugar is a likely conveyor of thermophilic organisms to the canned product. Therefore, bacteriological examination of sugars should be carried out as a routine test. The chemical tests that should be given to the sugar are those for its sucrose content, for dirt, invert sugar or glucose, protein, ash and sulphur dioxide.

Sucrose. This is usually tested for polarimetrically. The polarimeter and its special form adapted for sugar work, known as the saccharimeter, are well-known physical, analytical instruments of which there are numerous varieties upon the market. In sugar work it is usual to use a saccharimeter, and the illumination for the instrument is a good white light, inasmuch as the principles of the polarimeter have been adapted by means of quartz wedges in the optical design to utilise the D-line of the spectrum. The dial of the instrument is divided into segments corresponding with the percentage of sucrose in the solution, and therefore the sucrose percentage can be read off immediately. The batch of sugar being tested should be sampled carefully to ensure that a representative sample is chosen from the bulk. The " normal " weight of the sample is taken. The normal weight for modern instruments as adopted by the International Congress of Applied Chemistry is 26 grammes, and these must be dissolved in distilled water. This is clarified with basic lead acetate, a little alumina cream added, and the solution made up to 100 c.cs. and filtered. The required quantity of filtrate is filled into a saccharimeter tube, known as a 2-dm. tube, and its rotation measured in the saccharimeter at the required temperature, most of the saccharimeters being standardised for use at 20° C.

According to Ling,[9] the reagents are made up as follows: lead acetate; this should be in fine crystals, and 150 grammes mixed in an evaporating basin with 45 grammes of litharge and 25 c.cs. of water. The paste is allowed to remain at room temperature for 2 to 3 hours with frequent

stirring. Solution is accelerated by gently warming on a sand bath. The cream is then poured into 500 c.cs. of water and allowed to remain until the small amount of undesired sediment settles out. The alumina cream is made by pouring a cold 2 to 3 per cent. solution of alumina into dilute ammonia of specific gravity 0·98. The alumina is allowed to subside and is washed out by decantation until the supernatant liquid gives no reaction with barium chloride. This usually takes about a week. The amount of basic lead acetate to be used varies with the kind of sugar, the purest varying from 0·5 to 2·0 c.cs., darker products taking up to 10 c.cs. The required volume of alumina cream is about 5 c.cs.

Invert Sugar. The quickest method of carrying this out, and sufficiently accurate for cannery work, is the modification of the copper reduction method devised by Lane and Eynon.[8] The sugar solution is prepared of such strength that it contains from 0·1 to 0·3 grammes of invert sugar. Dry sodium oxalate is added to remove lime salts, and filtration is effected with keiselguhr. The filtrate is used for titration against Fehling's solution. A standard quantity, 10 or 25 c.cs., of mixed Fehling's solutions are measured into a flask of suitable capacity, and practically the whole of the sugar solution needed for complete reduction of copper is added at once. The approximate volume of sugar solution required is ascertained by preliminary titration. The flask containing the cold mixture is heated, and after the liquid has begun to boil it is kept at a simmer for 2 minutes. Three to five drops of methylene blue indicator are added and the titration with sugar solution is completed within a minute or so. Complete decolorisation of the methylene blue is the end point. The percentage of invert sugar may be calculated by the following formula :

$$\text{percentage of invert sugar} = \frac{100 \times 0·494}{VW}$$

100 c.cs. of the reagent requires 0·094 grammes of invert sugar for complete reduction. In the above formula V equals the volume of sugar solution required for complete reduction of 100 c.cs. of the reagent. This may be adjusted by multiplying by 10 or 4, according as to whether 10 or 25 c.cs. of mixed Fehling's solution were taken. W equals the weight of sugar sample in 1 c.c. of the sugar solution.

Dirt. This may be examined optically by dissolving a suitable portion in clean water. Every chemist will have his own idea of the proper amount to dissolve. The sugar solution is inspected and the presence of dirt will be obvious.

Protein. Should be determined by the Kjeldahl Gunning method, given in Chapter VIII.

Ash and *sulphur dioxide* can be determined by methods already described.

Syrup. Obviously, providing due care has been taken in the purchase of the sugar, the syrup will require no examination other than for sucrose concentration, and the method of determining this hydrometrically has already been described in Chapter II. Where metallic contamination from mixing tanks and other containers may be suspected then the tests given later in this chapter may be applied.

Milk

As already indicated in Chapter II, the successful processing of milk depends upon the control of its composition before it enters the evaporator, so that its heat coagulation shall be properly controlled, otherwise it will turn lumpy during the evaporating process. Of the numerous tests that have been advocated, those that are generally carried out on its reception at the factory—more commonly known as "platform tests," inasmuch as they are done at the receiving platform, or rather, while the milk is at the receiving platform—the most important, and those which should be made routine tests, are dirt, titratable acidity, alcohol, and fat content. Bacteriological examination is essential, as the bacterial content of the milk also has an effect upon the heat coagulation. Some factories, as a rough and ready guide to bacterial contamination, use the reductase test.

Dirt. This is observed by filtering a pint or half-pint through a cotton-wool disc; the dirt is left on the disc and may be judged according to factory practice.

Acidity. Usually expressed in terms per cent. of lactic acid. The method as given by Hunziker[10] is to titrate 17·6 c.cs. of the milk, to which has been added four or five drops of phenolphthalein indicator, against N/10 sodium hydroxide. The alkali should be run slowly from the burette whilst constantly stirring the sample, until the milk turns a faint pink throughout. If the end point is in doubt, another drop of indicator may be added, and this should turn pink on striking the milk. The number of c.cs. of hydroxide used, divided by 20, gives the per cent. of lactic acid.

Alcohol Test. This indicates the coagulability of the milk, and many factories use it as a rough and ready indicator of the amount of stabiliser to use with the milk. It will be remembered that in Chapter II. this is added before the milk goes to the evaporator. The test is carried out by placing 2 c.cs. of the milk in a small test-tube, adding an equal volume of 68 to 70 per cent. alcohol, and mixing by inverting twice whilst closing the tube with the finger. If a flaky white precipitate forms, it is regarded as indicating abnormality, and the amount of precipitate and size of the flaky particles indicate the degree of abnormality. When the mixture is shaken in a way that causes it to splash against the sides of the test-tube for about an inch above the surface of the liquid, the flaky particles become attached to the wall of the test-tube, where their number and

size may be noted. Mojonnier[11] emphasises the importance of the strength of the alcoholic solution, a difference of 3 or 4 per cent. having a considerable effect upon the result of the tests. Therefore, the figure of 68 or 70 per cent. should be adhered to.

Reductase Test. This is also known as the Methylene Blue Reduction Test. It is based upon the disappearance of the blue colour imparted to milk by the addition of a small amount of methylene blue, the time required for decolorisation being correlated in a general way with the bacterial content. It has been adopted as a provisional measure by the American Public Health Association, and the Association of Official Agricultural Chemists. The methylene blue solution should be 1 in 20,000 in distilled water. Methylene blue tablets for the making of such solutions are obtainable. 10 c.cs. of milk and 1 c.c. of the methylene blue solution are introduced into sterile test-tubes, and these are put in a water bath maintained at 100° to 104° F. The tubes are observed at settled time intervals, and the end point is denoted as the time elapsing until the colour has disappeared completely from more than three-quarters of the sample. Mojonnier quotes the following four classes into which milk may be divided by this method : class 1, milk keeping its colour for $5\frac{1}{2}$ hours or more, contains less than $\frac{1}{2}$ million bacteria per c.c. ; class 2, keeping its colour for at least 2 hours and less than $5\frac{1}{2}$ hours, contains $\frac{1}{2}$ million to 4 million per c.c. ; class 3, keeping its colour for more than 20 minutes and less than 2 hours, contains 4 million to 20 million per c.c. ; class 4, keeping its colour no longer than 20 minutes, contains 20 million per c.c.

Fat Content. This is usually carried out by the Gerber method as being the simplest and most rapid. Standard equipment is needed, including butyrometers, pipettes, centrifuge, and so forth, and it will be found that the majority of laboratory furnishers supply sets of these specially for this test. The reagents required include sulphuric acid of specific gravity 1·820 to 1·825, amyl alcohol of specific gravity 0·815 to 0·818—this is the fraction boiling between 124° to 130° C. To carry out the test, 10 c.cs. of the sulphuric acid are placed in the butyrometer and 1 c.c. of amyl alcohol. 11 c.cs. of the milk sample are then run on to the acid layer. Bolton[12] alters the procedure by adding the milk to the acid by running it on to the surface so that the acid and milk do not mix, and then adds the amyl alcohol in the same way. The butyrometer is then stoppered and shaken violently up and down in order to dissolve the casein. It is then placed in a water bath maintained at 160° F. for 5 to 10 minutes. It is then placed in the centrifuge and rotated for about 5 minutes at between 1,000 and 2,000 r.p.m. The fat collects in the graduated neck and the amounts may be read off as percentages of fat. Bolton recommends the carrying out of a blank experiment using water instead of milk, to see that no insoluble matter is obtained from the acid and alcohol.

Artificial Colours

The regulations existing in Great Britain prohibit the use of :

(*a*) Metallic colouring matters : Compounds of the following metals : Antimony, arsenic, cadmium, chromium, copper, mercury, lead, zinc.

(*b*) Vegetable colouring matter : Gamboge.

(*c*) Coal-tar dyes : Picric acid, or carbazotic acid ; victoria yellow, or saffron substitute, or dinitrocresol ; Manchester yellow, or naphthol yellow, or martius yellow ; aurantia, or imperial yellow ; aurine or rosolic acid, or yellow coraline.

Note. Naphthol yellow, or Manchester yellow, is not to be mistaken for naphthol yellow S, which is a permitted dye.

If artificial colours are purchased from any firm who make a speciality of producing them for use with foods, it is tolerably certain that prohibited dyes will not be supplied, in fact, a guarantee can invariably be obtained to the effect that the colour is suitable for use in foods for consumption in this country.

The necessity, therefore, seldom arises to identify the actual dye used, in fact, many of the food colours supplied are mixtures of two or more dyes which produce the desired tint.

It is, however, wise to make an examination for arsenic, which should not exceed 2 parts per million, in accordance with the recommendations of the Committee of the Society of Public Analysts.[13]

Further, a test of strength should be made, and the tint observed, for in spite of the care exercised by the colour manufacturers, different consignments of the same named dye sometimes show a considerable variation, both in strength and tint. The test, which is quite simple, consists of dissolving 0·5 grammes of the solid colour in 250 c.cs. of water, and taking 5 c.cs. of the solution in a Nessler glass, diluting to 50 c.cs. and comparing the tint and strength with a sample from a previous consignment of the same dye.

It should be remembered that an aqueous solution of a dye does not give the same tint when mixed with a coloured substance, and therefore, before deciding upon any particular colour for a definite purpose, it must be (1) tried out mixed with the material with which it is going to be used, and (2), *very important*, it must remain unchanged in tint by the temperature of processing to which it will be raised. Quite a number of excellent dyes show great change in tint when heated in the presence of salt.

Many countries issue in their food regulations a list of permitted dyes, and no others may be used. It is therefore desirable, when artificial coloured goods are intended for export, to consult the regulations applicable. It is quite a good plan to inform the colour makers from whom the colours are usually purchased, that a particular tint is required to colour certain products which are to be exported to such and such a country, and ask them to supply a dye which meets the requirements.

Much trouble can thus be avoided, and the frequently troublesome task of identifying a dye or mixture of dyes avoided.

With the exception of Armenian bole, a very finely ground oxide of iron, no metallic salts are used in Great Britain for food colouring. This colour is particularly suited for imparting the desired tint to such substances as anchovy pastes and sauces. In the course of its preparation it is very difficult entirely to free it from arsenic, and it must therefore invariably be tested for that substance.

When the identification of a dye or mixture of dyes has to be undertaken the reader is referred to the scheme given by Allen.[5]

Spices

On account of the relatively high prices obtained for these aromatic vegetable substances their adulteration is not unlikely, and this may be brought about either by the addition of foreign vegetable matter of low cost, by the admixture of the spice with an exhausted spice of the same variety, or sometimes by the addition of mineral matter.

Nearly all spices exhibit characteristic microscopical features, and in no case should the preparation and examination of microscope slides be omitted. For a full description of the microscopical appearance of the spices the reader is referred to Greenish.[14]

In the examination of spices, chemical methods of analysis are of less importance, but they will detect the adulteration of a spice with exhausted spice of the same kind, and also the presence of added mineral matter, and it is therefore desirable to determine the ash, and the ether extract.

The Ash. Two grammes of the sample are ignited in a platinum crucible, first at a dull red heat, and subsequently in a muffle furnace. After the carbon has been burnt off the residue is weighed, and the amount calculated.

Ether Extract. A weighed quantity, about 2 to 3 grammes, is placed in a continuous extraction apparatus such as a Soxhlet, and extracted with dry ether of sp. gr. 0·720, for a period of 12 to 16 hours. The ethereal extract is then poured into a tared evaporating basin, and the ether allowed to evaporate spontaneously. The basin is then placed in a desiccator where it is allowed to remain for at least 10 hours. It is then weighed, and the weight of the material calculated as the total ethereal extract. The dish is then transferred to a cold air-oven and the temperature gradually raised to 100° C. It is maintained at that point for 5 hours, and then raised to 110° C. After a further period of 2 hours the dish is cooled in a desiccator and weighed. It is returned to the oven for a further treatment by heat and again weighed. This operation is continued until the weight is constant. The final residue is the non-volatile ether extract, and the difference between it and the total extract is the volatile extract. The above method is that recommended by Richardson.[15]

Ginger

In the case of *ginger* the adulteration with exhausted ginger, formerly a common practice, can readily be detected by a determination of the cold water extract, the details of which are as follows :

Two grammes of the sample are placed in a 200 c.c. flask, and 100 c.cs. of water added. The flask is thoroughly shaken at intervals of 15 minutes for a period of four to five hours, and then allowed to stand over-night, or for at least twelve hours. It is then filtered, and 50 c.cs. evaporated to dryness in a weighed porcelain basin. It is then dried to constant weight. Gingers from different sources show a considerable variation in the amount of cold water extract they yield, but the minimum figure is usually considered to be 8·0 per cent. A lower amount than this indicates the presence of exhausted ginger, if no other adulterant can be found as the result of microscopical examination.

Ash and Ether Extract

The ash and ether extract of some of the commoner spices are as follows :

	Ash %	Ether Extract.	
		Volatile %	Total %
Mace (15)	2·01	7·3	22·5
Nutmeg (16)	2·2	2·9	31·0
Pepper (White) (16) ..	1·8	0·7	6·9
Pepper (Black) (16) ..	5·1	1·3	8·4
Cinnamon (16)	4·8	1·5	1·8
Pimento (15)	5·5	2·7	5·3

For the more complete analysis of spices and fuller details of composition the reader is referred to Leach's " Food Inspection and Analysis."

Essential Oils in Essences

There is no method which can be relied upon to give strictly accurate results, but the following may be regarded as reasonably reliable :

25 c.cs. of the sample at 15·5° C. is mixed with 90 to 100 c.cs. of water in a separating funnel. Sufficient salt is then added to saturate the water. 50 to 100 c.cs. of petroleum ether (b.p. below 60° C.) is then run in, and the whole agitated. After allowing to stand, the lower layer is removed, placed in a separating funnel and again agitated with 25 c.cs. of petroleum ether. The bottom layer is then run into a distillation flask, to which are added 25 c.cs. of a saturated solution of salt in water. The alcohol is then distilled off, and the percentage originally present in the essence calculated.

The petroleum ether extract is dried over anhydrous sodium sulphate, and evaporated by passing through it a stream of dry air, during which the flask is maintained at 30° C.   The residue consists of the total oil originally present in the essence.

Salt

As mentioned elsewhere, the presence of even small amounts of the salts of calcium and magnesium in this substance may have a deleterious effect upon the finished canned product, and for this reason care must be taken to ensure that the salt used does not contain more than a trace of these substances.

Total Calcium in Salt.   50 grammes of the sample are dissolved in water, the solution rendered alkaline with ammonia, and the calcium determined by precipitation and subsequent titration, as described under water analysis.   The residue is treated with a few c.cs. of a strong solution of sodium hydrogen phosphate in the presence of much ammonia.   The magnesium thrown down is filtered off, the precipitate washed till free from chloride, and after ignition weighed as magnesium pyrophosphate. For details of the *modus operandi*, see under water analysis in Chapter VII.

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CHAPTER VI

EXAMINATION OF THE CAN

FOR ascertaining the thickness of the coating of tin on tinplate, the rapid method of K. Heuberger[1] will be found sufficiently accurate for all general purposes. It is as follows :

Pieces of plate measuring 10 by 5 cms. are cut from three or four sheets of a consignment. These pieces are then cut into shavings and placed in a flask of about 250 c.cs. capacity, closed with a valve containing sodium bicarbonate solution. 50 c.cs. of water and 75 c.cs. of concentrated hydrochloric acid are then added, and the flask is gently warmed until solution is complete. The solution is then boiled for a few minutes, and rapidly cooled in running water. A further 20 c.cs. of concentrated hydrochloric acid (1 : 3) are added, and about 1 c.c. of a 1 per cent. solution of starch. The solution is then at once titrated with deci-normal iodine solution, until a faint permanent blue colour persists.

The reaction taking place is as follows :

$$SnCl_2 + 2HCl + I_2 = SnCl_4 + 2HI$$

One c.c. of deci-normal iodine is equivalent to 0·00593 gms. of tin.

From the weight of tin found, the thickness of the coating of this metal may be calculated. It should be remembered that the tin coat is present on both sides of the sample.

It has been found that the results are always a trifle higher than those obtained by the much more tedious method of volatilisation of the tin in a current of chlorine, but the error is not large enough to be of serious consequence in ordinary commercial analyses. It should be understood that it is at present practically a manufacturing impossibility to produce tinplate with an absolutely uniform coating of tin, even on the surface of a single plate, so that in examining a consignment to ascertain its compliance with a definite specification, samples must be taken from several sheets drawn from more than one box of plates. The National Canners' Association (U.S.A.) have adopted the following standards for grades of tinplate, according to the purpose for which it is required. In general, the plates with the heavier coating are to be recommended for fruits, etc., of an acid nature. The grades are as follows :

G

Grade.	Weight of tin per base box in lbs
A	0·85 to 0·95
B	1·05 ,, 1·15
C	1·25 ,, 1·35
D	1·45 ,, 1·55
E	1·725 ,, 1·825
F	2·00 ,, 2·20
G	2·75 ,, 3·25

A base box of tin is the unit by which tinplate is sold. It contains 112 sheets, each 14 by 20 ins., or 31,360 sq. ins. Counting both sides of the sheets, the base box contains 62,720 sq. ins. of tinned surface.

Evenness of Coating of Tin

Although the gelatine-ferricyanide test has from time to time been subjected to a certain amount of criticism—chiefly on the grounds that it not only gives a positive result with untinned iron, but may also show regions of tin-iron alloy—there is no doubt that it serves as an excellent guide for distinguishing between bad and good plate.

The test is carried out as follows : A solution is made containing 10 per cent. good-grade gelatine (free from iron) and 3 per cent. potassium ferricyanide. While still in a liquid condition, this is poured upon the surface of the sample of tinplate under examination. The latter has previously been washed with benzene, or some other volatile grease solvent, in order to remove oil from its surface. The plate is then put aside for some hours, preferably in a cool place, during which period the gelatine will set and develop blue spots wherever it has come into contact with exposed iron. The size of the spots cannot be regarded as having a direct relationship to the size of the particles of uncovered iron ; on the other hand, a blue spot does definitely indicate exposed iron, and plate showing many such spots will very probably give rise to black discoloration in the finished food product. It does not seem to follow that a plate bearing a heavy coating of tin will necessarily show greater freedom from uncovered spots of iron than will a relatively lightly coated plate. For many purposes, the evenness of the tin coating is of more importance than thickness of the tin upon the plate.

The illustrations given show the application of the test to good and bad quality plate. It will be observed that the difference is very obvious.

Solder

Solder is usually purchased under a guarantee in regard to the percentage content of tin, and it is seldom necessary to determine the amount of lead and /or bismuth which it contains. An average sample is obtained by cutting shavings from several bars or sticks with a sharp knife; 0·5 gm. is weighed into a porcelain basin and dissolved in a small quantity of nitric acid (90 per cent. acid and 10 per cent. water), care being taken, by

FIG. 39

THIS AND FIG. 40 SHOW THE RESULTS OF THE GELATINE-FERRICYANIDE TEST APPLIED
TO VARIOUS SAMPLES OF TINPLATE, STAMPED OUT ON CAN ENDS. THE DARK SPOTS
INDICATE EXPOSED, I.E., UNTINNED IRON. THE LETTERS " A B C " HAVE BEEN SCRATCHED
ON THE LEFT SPECIMEN TO DEMONSTRATE THAT IT IS EXPOSED IRON WHICH GIVES RISE
TO THE BLUE COMPOUND

Courtesy of " Food "

FIG. 40

TWO RATHER BETTER SAMPLES OF TIN PLATE THAN THOSE TREATED IN FIG. 39, ALSO
TREATED BY THE GELATINE-FERRICYANIDE TEST

Courtesy of " Food "

Fig. 41

Courtesy of " Food "

covering the dish with a watch glass, to avoid loss by spurting.   When solution has been effected the cover is rinsed into the dish, and the contents evaporated almost to dryness on a steam bath.   The precipitate, which consists of stannic oxide, is transferred to a filter paper by the use of water, and then washed three or four times.   The funnel is then transferred to the hot-air oven, and when dry the precipitate is removed as completely as possible from the filter paper by brushing it into a tared crucible.   The filter paper is incinerated in a platinum coil, and the ash allowed to fall into the crucible containing the stannic oxide.   A few drops of concentrated nitric acid are added, and the crucible is gently warmed until the acid has been driven off.   The temperature is then raised to dull red heat.   After cooling, it is weighed, and from the weight of stannic oxide obtained the percentage of tin in the solder is calculated.

If it be desired to determine the amount of lead present, the solution and washings from the tin oxide precipitate are treated with an excess of dilute sulphuric acid (1 : 3), and then with sufficient alcohol (methylated spirit) to increase the bulk of the liquid to three times its original volume.   The precipitate is allowed to settle, filtered off, and washed with alcohol until the washings are free from sulphuric acid.   The precipitate is dried in the oven, and removed as completely as possible from the filter paper, which is ashed in the manner described above.   The ash is treated with one or two drops of strong nitric acid, and finally with a few drops of concentrated sulphuric acid to convert into lead sulphate any lead nitrate which may have been formed.   From the weight of lead sulphate found, the percentage of lead present in the solder may be calculated.

<div align="center">

Factors Required.

$SnO_2 \times 0 \cdot 787$ gives Sn.

$PbSO_4 \times 0 \cdot 6829$ gives Pb.

</div>

For various purposes, it is sometimes desirable to use solder of a lower melting point than that which can be obtained by the alloying of tin and lead, and a percentage of bismuth is employed in the composition of the solder, the amount used depending upon the melting point required. It therefore becomes necessary to determine the percentage of bismuth when such solders are used.   The separation of bismuth and lead is somewhat troublesome, but if the following technique be closely followed no undue difficulty will be experienced.

Take $1 \cdot 0$ gm. of the solder, treat with nitric acid as in the determination of tin, filter off the metastannic acid, and if necessary concentrate the filtrate and washings to a volume of about 300 c.cs.   Proceed according to the method of Little and Cahen,[2] which is as follows :

Nearly neutralise the solution obtained above with sodium carbonate solution (added from a burette) until the liquid is distinctly opalescent. There should be no visible precipitate. $10 \cdot 15$ c.cs. of a ten per cent.

solution of sodium formate are now added slowly and with constant stirring, and then 5 to 10 drops of a 5 per cent. solution of formic acid. This causes a white precipitate to settle out in the cold. The solution is heated to boiling, and kept in ebullition for five minutes. After allowing the precipitate to settle, the liquid is decanted while still hot, being passed through a filter paper. The precipitate is finally removed to the filter paper, and washed several times with boiling water. The original beaker in which the precipitation took place is then placed under the funnel, and the precipitate is dissolved in hot dilute nitric acid, the solution being allowed to flow into the beaker. The volume of nitric acid used should be as small as possible. The filter paper is washed with cold water, and the volume of the solution and washings made up to about 300 c.cs. The precipitation of the bismuth as basic formate is then repeated. The precipitate is again collected and washed several times with hot water, the washings being rejected. The bismuth precipitate is then dissolved in hot dilute nitric acid, the solution evaporated to dryness on the steam bath, and again taken up in a few c.cs. of dilute nitric acid.

The double precipitation of the bismuth as basic formate is necessary in order completely to separate it from the lead.

The amount of bismuth is then determined volumetrically.[3] Sufficient ammonia is added to neutralise the nitric acid present, and then about 0·5 gm. of solid ammonium oxalate is added. The liquid is boiled, the precipitate allowed to settle, the supernatant liquid decanted through a filter paper, and the precipitate again boiled with about 50 c.cs. of water. Filter and wash the precipitate until the washings are free from oxalate (test with calcium chloride solution). Dissolve the precipitate in about 10 c.cs. of dilute hydrochloric acid (1 : 1). Heat to effect complete solution, dilute to 250 c.cs. with hot water, add dilute ammonia until just neutral, and finally dissolve the precipitate formed in dilute sulphuric acid (1 : 4 vol.). Heat the solution to 60° C., and while hot titrate with deci-normal potassium permanganate solution until a permanent pink colour is produced.

One c.c. of N /10 permanganate is equivalent to 0·0104 gm. of bismuth.

Presence of Zinc in the Finished Can

On account of its suitability, zinc chloride is very largely employed in the preparation of soldering fluxes. Unless precautions are taken to guard against the danger, traces of zinc are likely to remain in the can, and subsequently find their way into the food. It is important therefore that the canning factory should be equipped with efficient can-washing machinery, and it is for the chemist to ascertain whether or not can washing is being efficiently carried out. This necessitates testing for traces of zinc, which can without difficulty be carried out as follows :

The seam of the can is thoroughly washed with hot water, and the

washings concentrated to small bulk in a beaker. To 1 c.c. of a 10 per cent. solution of resorcinol in 90 per cent. alcohol, add 1 c.c. of dilute ammonia; then add 1 c.c. of the solution suspected of containing zinc. In the presence of even a trace of this metal, the purple colour produced by the action of ammonia upon resorcinol changes first to golden-yellow, then to green, and finally to deep blue. The action may be delayed for several hours if only a minute quantity of the zinc is present, and it is therefore advisable to carry out a control test at the same time in order that the change in colour may be observed. The test is sensitive to (2×10^{-6}) gm. of zinc in 1 c.c.[4]

Rubber Preparations for Sealing Joints in Sanitary Cans

These consist of either an emulsion of specially prepared latex in dilute ammonium hydroxide, or a solution of the rubber in a solvent, usually a low boiling point petroleum spirit. The former should be examined to ascertain that it contains the specified quantity of solid matter. This can be ascertained by evaporating a weighed quantity of the sample to dryness on the water bath, and finally heating in the hot-air oven at 105° C. until the weight is constant.

The amount of ammonia present may be determined by a direct titration of the emulsion with deci-normal sulphuric acid, using 10 gms. of the sample. 1 c.c. of N/10 sulphuric acid is equivalent to 0·0017 gms. ammonia (NH_3).

A typical analysis of an emulsion is as follows:

Solid matter	18·5	per	cent.
Ammonia	0·9	,,	,,
Water ..	80·6	,,	,,

The rubber solution should be examined in order to ascertain the boiling point range of the solvent used, which should not exceed 90° C. If a higher boiling point solvent is used in the preparation of this material, there is a likelihood of its being incompletely removed in the lid-drying chamber, through which all lids and bottoms are passed during can manufacture. Any remaining solvent will impart a most undesirable taste to the food in the can, rendering it quite unfit for sale.

About 100 c.cs. of the solution are placed in a distillation flask, fitted with a thermometer, and distillation is continued until all the liquid has distilled off. Care must be taken towards the end of the operation to avoid the application of too much heat; otherwise some of the remaining rubber may be decomposed, and thus give rise to erroneous results. If preferred, the distillation may be carried out by the use of a brine or oil bath.

If it be desired to ascertain the amount of rubber in the solution, a weighed quantity of this latter is evaporated to dryness on the steam bath, the operation being finished in the hot-air oven.

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IT would be difficult to place too much emphasis upon the importance of an adequate and suitable water supply for the canned food factory, and yet it is probable that it does not receive the attention it merits. Purity is, of course, of prime importance, but there are other factors to be considered if the water is not to have a deleterious effect upon the ultimate products. If for some reason the water does not lend itself readily to the purposes required, it is seldom that it cannot be satisfactorily treated. Where the erection of new premises is contemplated, due attention should be directed to the quality and quantity of the water available, and if treatment is needed, provision can be made for water treating plant in the original plans. It does not necessarily follow that in municipal areas the water, although beyond reproach from the point of view of organic purity, may be the best suited for canning. Consideration should be given to purity, hardness, freedom from metallic contamination, taste, colour, action upon metals, bacterial contamination and p_H value.

Causes of Hardness and its Removal

The hardness of water is due to the presence in it of the bicarbonates, sulphates, and less commonly the chlorides and nitrates of calcium and magnesium. The bicarbonates form the temporary hardness and the sulphates, nitrates, and chlorides the permanent hardness. If the total hardness of the water—that is, the combined temporary and permanent hardness—exceeds 10 to 12 parts per 100,000, the water should be softened before use, particularly where fruit and vegetable canning is in operation. The salts of calcium and magnesium possess the property of combining with the pectous substances present in such vegetables as peas and beans to form insoluble pectides, and material brined and treated with water containing these salts is very liable to become coated with a hard outer shell or skin which renders it tough and therefore unpalatable. A water containing much temporary hardness will throw down a heavy precipitate of calcium carbonate upon boiling ; this is likely to produce cloudy liquor in the can, and thus spoil the appearance of the pack.

Where operations are conducted upon a very small scale, temporary hardness of water can be removed by boiling and subsequent settling, but

such a method is impracticable and far too costly where anything but the smallest volume of water is to be handled.

There are two well-known means by which both the temporary and permanent hardness of water can be removed—the lime-soda treatment and the base-exchange treatment. The chemical reactions are dealt with later in this chapter. In the former, all the hardness is removed in the form of carbonates (the magnesium salts will come out of solution as hydrates) and the treated water will contain an amount of sodium sulphate, dependent upon the degree of permanent hardness of the original water, and also a slight excess of hydrate and carbonate alkalinity, dependent upon the quantities of the reagents used in the softening process. As in some instances, particularly when dealing with delicate fruits, an excessive alkalinity is objectionable, care should be exercised to guard against this condition in the water. The water will also hold in solution a small amount of calcium carbonate, which is soluble to an extent of $1\cdot3$ parts per 100,000 parts water and, if magnesium salts were present in the original water, magnesium hydrate to an amount of $0\cdot93$ parts per 100,000. It is not therefore possible to produce water of zero hardness by the lime-soda method. But it is very seldom that a completely softened water is needed in the canning industry. A hardness of 4 to 5 parts per 100,000 will have no harmful effect upon any of the materials.

The base-exchange treatment converts all the bicarbonates of magnesium and calcium to sodium bicarbonate, and the sulphates, nitrates and chlorides to the corresponding sodium salts. A water of zero hardness is thus produced, but it will contain much sodium bicarbonate (if the temporary hardness of the original water was high), and excess of bicarbonate of sodium may not always be desirable in a cannery water. A further disadvantage of a water of zero hardness is that it is likely to exert some solvent action upon galvanised piping, and to possess corrosive properties towards iron, especially at temperatures in the region of 212° F. or over.

The causes of the corrosive action of many waters are still obscure, and therefore no definite line of treatment can be laid down. A corrosive water usually shows greater activity at high temperatures ; such water will have a greater tendency to act upon the tinplate, particularly during the period of processing, and may lead to trouble. A water with an excessively corrosive action is unsuitable for food canning.

There are quite a number of natural waters which possess a corrosive action, due in some cases to acidity—such as waters from peaty districts — in others, to the pressure of saline matter, under special conditions which are not fully understood, an example being common salt along with much dissolved oxygen which, when present to an extent exceeding 50 parts per 100,000, causes the heated water to be actively corrosive. The trouble in the former instance is readily overcome by lime or other

treatment, but in the latter, the removal of salt presents difficulties. It can be brought about by the use of certain synthetic resins.[1] If this method of treatment proves a commercial possibility, it is likely to find wide application, for, in addition to removing salt, the resins render the water perfectly soft. When circumstances demand that a corrosive water has to be used, it is desirable to leave in it some scale-forming material, for this will soon produce upon the pipes, etc., a thin protective coating which will arrest the corrosive action. In one or two isolated cases water is softened to remove one or more objectionable features, and then re-hardened to the requisite degree to overcome its corrosive action.

Discoloration due to Iron

It has for some time been recognised that the discoloration of canned foods is nearly always to be attributed to the formation of salts of iron— usually the sulphide, but sometimes a tannate, tannin being a common constituent of many spices. Sulphur enters into the composition of many foodstuffs, as part of the protein molecule. It is practically impossible to avoid some contamination of the material with iron during its passage through the canning factory, but it is important to reduce this source of danger to the lowest possible limit, and therefore the use of water containing iron—in excess of a minute trace—must be avoided. The sources of quite a number of municipal and private water supplies are deep wells, and in certain parts of England deep well water frequently contains a sufficient amount of iron to render it unsuitable for canning work, unless the iron is removed. Such water is more often than not quite clear when first drawn, but after a few hours will manifest an opalescence due to the precipitation of some of the iron held in solution. Water, on account of the free carbon dioxide it sometimes contains, and in the absence of its full quota of dissolved oxygen, has a solvent effect upon iron oxide (Fe_2O_3), and bicarbonate of iron is formed. When water containing iron in this form is exposed to atmospheric influence, the bicarbonate is converted to ferric hydroxide, which may be precipitated or remain in a colloidal state. This deposition of iron will take place in vessels in which the water is stored, and an undue proportion of iron may find its way into the material being packed. Iron is sometimes found in water in organic combination, but it is doubtful if in this state it is likely to be of much significance to the canner. The iron salts may be removed from the water by either of the processes of softening already mentioned, but should the water be so low in hardness as to render softening unnecessary, the iron may be removed by treatment with lime, or sometimes by aeration only. The state of combination of the iron has some bearing upon its effect on canned foods, so that it is not possible to state any definite maximum limit for the amount of iron permissible in a cannery

water, but as a rule two parts of iron per million parts of water must be regarded as excessive.

Lead and Copper

The presence of copper, even in small traces, is likely to have an even greater tendency to produce discoloration than has iron, but because it is very seldom present in natural waters in Great Britain, trouble arising from its interference is rare, unless the water, being of an acid nature (such as moorland and peaty waters), is allowed to stand in copper tanks or is circulated through copper pipes.

Both moorland and peaty waters possess a tendency, on account of their acid nature, to dissolve lead,[2] so that the presence of this metal in water is more likely to cause discoloration troubles than copper, for it frequently happens that water is conveyed in lead pipes. Another danger may arise through the use of plumbo-solvent water; it will possess an action upon the lead used in the soldering of the cans, and may not only give rise to discoloration but may even cause illness from the consumption of lead-contaminated food. It is important therefore to determine the hydrogen ion concentration or p_H value of the water, and if the figure obtained indicates that the water is of an acid nature, steps should be taken to inquire into its history to ascertain if it has come into contact with lead, or is likely to have done so. Various methods will render water inactive as regards lead—such as the addition of lime and soda ash, or a solution of silicate of sodium—but where water is found to possess a plumbo-solvent action, it may be advisable to call in the help of a specialist, as the nature of the treatment will vary according to the composition of the water.

Taste in Water

If a water is palatable, although somewhat flat in taste (as it will be if softened), its suitability for canning may be safely assumed, but if, on the other hand, it possesses a disagreeable flavour, the cause of this must be removed. Taste is frequently accompanied by odour, especially when due to organic contamination, but salts of iron, manganese, etc., will impart a metallic flavour even when present in traces only, without any noticeable smell. Water subjected to chlorination and imperfect dechlorination will possess a very distinct and disagreeable flavour, which may persist throughout the canning process. A water, to be regarded as of a satisfactory nature, should possess neither taste nor smell even when raised to the boiling point.

Taste in water may sometimes be attributed to the presence of a high amount of sodium chloride, and when this reaches or exceeds 100 to 150 parts per 100,000 the flavour will be apparent to the average palate, although it is improbable that this amount of salt will have a deleterious

effect upon the quality of a pack. The presence of magnesium salts in excess will impart a bitter taste to the water, and unless these can be removed, such water will, for this reason, be unsuitable for canning.

It is doubtful whether any supply of water is entirely free of bacteria, but a water showing a high bacterial count must be regarded as undesirable. Micro-organisms are likely to bring about fermentative changes in vegetable matter left for a period immersed in water or weak brine and may also necessitate a longer period of processing, since the number of bacteria present in a food has an important bearing upon the temperature and length of time needed effectively to preserve it.

Another group of undesirable organisms is the " iron bacteria." They are commonly, though not always, found in waters containing iron. The iron bacteria have been exhaustively studied by Professor Ellis, of Glasgow.[3] These organisms possess the power of abstracting iron not only from the water in which they exist, but also from the iron pipes, etc., used to convey the water, and as the storage and oxidation of iron by the bacteria is continuous, a large accumulation of iron hydroxide will occur in course of time, and may even lead to the blockage of pipes. Water thus infected can lead to discoloration troubles.

Pollution

Should indications of this kind of impurity be obtained, the water would of necessity need treatment to render it sufficiently pure, or alternatively its use would have to be abandoned.

The chemical and bacteriological examination of water is a task the food-canning chemist will certainly have to undertake, and if he does his job properly it will be one of the routine analyses which will need carrying out frequently.

Chemical Examination

The various determinations required in the analysis of water are those of suspended matters, total solids in solution, free and saline ammonia, albuminoid ammonia, nitrogen as nitrates, nitrogen as nitrites, oxygen absorbed, and chlorine.

The methods of analysis given have been found by experience to produce the most accurate results, consistent with rapidity and ease of manipulation. They by no means cover the many and various ways known for the determination of the analytical data needed for the examination of water.

It is usual to include the determination of the hardness of the water, although this has no direct bearing upon its potability, unless the water is exceptionally hard, and contains sufficient mineral impurity to produce a " taste."

Other determinations can, of course, be made, but under ordinary conditions sufficient information can be gleaned from these (coupled with the bacteriological examination) to allow an opinion to be formed as to the suitability of the water for drinking and food-manufacturing purposes, provided the mineral constituents are not such as to have a harmful effect upon the products.

Sampling, etc.

The Collection of the Sample. The most suitable receptacle is a stoppered Winchester quart, which has been previously well cleaned by rinsing it with concentrated sulphuric acid, followed by a copious washing with distilled water, until the washings show no acidity. If the sample is to be drawn from a tap or pump, it is desirable to allow sufficient water to run to waste, until all that may have been standing in the pipe or rising main has been cleared from the system. The bottle should then be *completely* filled, so as to remove any gases present, and then completely emptied, this operation being repeated at least once, but preferably twice. Then fill nearly to the stopper and tie down tightly. Do not put the stopper down on a shelf or on the ground while the sample is being collected ; it should be held in the hand by the top, and rinsed with water before insertion into the neck of the bottle.

Suspended Matter. It is unlikely that there will be sufficient of this to render the water anything more than very slightly turbid; if there is, then this fact alone may make the water unsuitable for manufacturing purposes, unless it can be subjected to a process of filtration. It is highly probable that the water will contain only a trace of suspended matter, or none at all. In the former case the sample should be allowed to settle for some hours, when a pipette can be inserted to the bottom of the bottle, and a drop of the water containing the settled suspended matter withdrawn. This should be placed upon a microscope slide and examined. Particular notice should be taken of infusoria, ciliata or flagellata, hair (usually of animal origin), vegetable debris, etc. Some information may thus be obtained about the history of the water. A small quantity of sandy matter is very frequently found, but as the sources are likely to be many, undue significance must not be attached to the presence of this substance.

Total Solids in Solution

Where the suspended matter is too small to determine, and, therefore, cannot have a material effect upon the total solids, filtration of the water is not called for. 200 or 250 c.cs. of the water are evaporated to dryness in a tared platinum dish over a steam hole, and when evaporation is complete, the dish is transferred to a hot-air oven maintained at a temperature of 180° C. for a period of one hour. It is then removed to a

desiccator and weighed.   It should then be returned to the oven for a further 20 minutes and again weighed.   The temperature of 180° C. is adopted because at this temperature magnesium sulphate retains a definite proportion of water, and calcium sulphate loses the whole of its water of crystallisation, the results consequently being much more uniform and satisfactory than at a lower temperature.[4]   These solids may be retained for the determination of chloride, or the chloride may be arrived at by the titration of a measured quantity of the water with standard silver nitrate.   When the volume of the sample is sufficient to allow of it, it is preferable to determine the chlorides in an aliquot of the sample, and not upon the solids.

Free and Saline Ammonia

Nearly all waters contain some free or saline ammonia, which probably exists in combination with an acid, such as carbonic acid.   The method employed in its determination is as follows :

Required : Ammonia-free   water,   Nessler   solution,   and   standard ammonium chloride solution.

Nessler Solution.   Dissolve 90 grammes of potassium iodide in 125 c.cs. water, and pour this upon 35 grammes of mercuric chloride contained in a glazed porcelain dish or mortar.   Stir the mixture until the solid matter has dissolved and make up volume to 1250 c.cs. by the addition of water. Now add 227 grammes of potassium hydroxide, and when dissolved and cool add a saturated solution of mercuric chloride, until a slight permanent precipitate is formed.   Make up the volume to 1500 c.cs.; then allow the solution to clear by standing, after which decant the clear solution. Keep this stock solution in a rubber-stoppered bottle, and decant a portion from time to time for use.

Standard Solution of Ammonium Chloride.   Dissolve 3·15 grammes of ammonium chloride in water, after drying the pure salt in an oven at 105° C., and dissolve in one litre of water.   Take 10 c.cs. of this solution and dilute to 1 litre ; 1 c.c. of this solution equals 0·01 mg. ammonia.

The determination must be carried out in a laboratory free from any ammonia fumes, the presence of which, even in very small amounts, will entirely vitiate the results, ammonia being so exceedingly soluble in water.   Unless a special laboratory can be set aside for water analysis, it is a desirable precaution to remove all bottles of ammonia from the room before beginning the analysis.

A distillation flask of about 1,000 c.cs. capacity is fitted to a 20-inch Liebig condenser, or preferably to a double surface condenser.   A few hundred c.cs. of ordinary tap water are introduced into the flask, which is heated, and the water allowed to boil until the condensate is found to be free from ammonia when tested with the Nessler solution.   The purpose of this operation is to free the apparatus from ammonia.   The flask is

then rinsed, preferably with a little dilute hydrochloric acid, which must be entirely removed, and then 500 c.cs. of the sample under examination are introduced into it, followed by about 1 gramme of freshly ignited pure sodium carbonate. The flask is then connected to the condenser, heated, and the distillate collected in quantities of 50 c.cs. in Nessler glasses. As a rule, it will be found that all the ammonia has distilled over with the first 100 to 150 c.cs. of the water.

Nesslerising

Fill a burette with a quantity of the standard ammonium chloride solution, and make up various strengths of ammonia by running small quantities of the solution into Nessler glasses, such as 0·5 c.c., 0·8 c.c., 1·5 c.c., and make the volume up to 50 c.cs. with ammonia-free water. Place these upon a white tile, and with them put the three 50 c.c. fractions distilled from the sample. Now add to the standards and the fractions, 2 c.cs. of Nessler solution, and judge, by the depth of the colour produced, the quantity of ammonia present in the water. It is desirable to conduct the operation in this manner, because the colour produced by Nessler solution rapidly changes, and consequently, if the reagent is added to the fractions before the standards are made up, the time elapsing will lead to inaccuracy. This precaution entails the use of rather more ammonia-free water, and extra Nessler solution, but is desirable where accuracy is aimed at. It sometimes happens that all the free and saline ammonia does not distil with the first 150 c.cs. of water, and therefore, before finishing the distillation, it is necessary, in all cases, to continue the process until the distillate gives no colour with Nessler solution. Every 50 c.cs. which shows the presence of ammonia must be matched against a standard. The total ammonia thus determined is then expressed in parts per 100,000 parts of the water.

An example is : 500 c.cs. of a sample of water. The first 50 c.cs. of distillate was matched by 0·5 c.c. of standard ammonium chloride solution, and the second 50 c.cs. of distillate by 0·3 c.c. of the standard, the third 50 c.cs. being ammonia-free. Therefore, the total free and saline ammonia in the sample was equivalent to 0·8 c.c. of the standard solution, that is, it was 0·0016 parts per 100,000 parts of the water.

The interpretation of the results of the analysis will be discussed subsequently, so that no comment will be made at this stage upon the significance of free and saline ammonia in water.

Albuminoid Ammonia

The figure obtained may be regarded as a rough idea of the amount of nitrogenous organic matter in solution in the water. The determination is made upon the residue in the distillation flask after the free

ammonia has been removed.   50 c.cs. of freshly boiled alkaline permanganate solution are added to the water in the flask, and the distillation conducted in the same manner as that employed in the determination of the free ammonia.   The addition of the alkaline permanganate is liable to lead to some " bumping " in the boiling flask, and this may be overcome by the introduction of a few pieces of *freshly ignited* pumice or a few small pieces of clay pipe stem.   Generally the whole of the albuminoid ammonia will distil over in the first 150 c.cs., but occasionally 200 or even 250 c.cs. may need to be distilled before the distillate is found to be free when tested with Nessler solution.

Preparation of Alkaline Permanganate Solution.   Dissolve 10 grammes potassium hydroxide and 0·5 gramme potassium permanganate in 50 c.cs. of water.   Boil the solution for some minutes until its volume is concentrated to about 25 c.cs., and then add to the water under examination in the retort.

The Nesslerising is carried out in precisely the same manner as that described under the determination of free and saline ammonia.

Nitrous Nitrogen

The simplest method is to employ the now well-known Griess-Ilosvay test.   The reagents required are :

Sulphanilic acid solution.   Dissolve 0·5 gramme in 150 c.cs. of 20 per cent. acetic acid.

Alpha-naphthylamine hydrochloride solution.   Dissolve 0·2 gramme in 10 c.cs. of 20 per cent. acetic acid with the aid of heat.

Standard solution of sodium nitrite.[4]   Dissolve 1·1 grammes of pure silver nitrite in about 500 c.cs. water ; if necessary, employ heat.   When cold, add 0·5 gramme pure sodium chloride, and dilute to 1 litre.   Allow to stand in the dark, decant the supernatant liquor.   Keep in a dark place.   1 c.c is equivalent to 0·1 mg. N.

Take 50 c.cs. of the water sample in a Nessler glass and add to it 2 c.cs. of each of the above reagents.   Match up the pink colour produced with portions of the standard sodium nitrite solution in 50 c.cs. of water. The test will readily detect the presence of 1 part of nitrous nitrogen in one million parts of water.

At one time a test for nitrites in water depended upon the reaction between an iodide and nitrite in the presence of an acid, whereby the liberated iodine was detected by starch, but since the practice of purifying water by the use of chlorine has become greatly extended, and as free chlorine liberates iodine from an iodide, the test can no longer be regarded as a reliable one for nitrites in water.

Nitrates (Nitric Nitrogen)

There are many methods available for this determination, but the most reliable one depends upon the reduction of the nitrates to ammonia, and the determination of this by distillation.

The reduction is brought about by immersing in the water a quantity of zinc-copper couple.

Immerse a few grammes of pure granulated zinc in a 3 per cent. solution of copper sulphate, and allow to stand for a few minutes until the zinc becomes coated with a firmly adhering black coating of copper. The film must not be so thick as to become detached when the zinc is rinsed with water. Usually 10 minutes' immersion is amply sufficient. The couple must be washed free from copper sulphate before it is introduced into the sample of water under examination.

One hundred c.cs. of the sample of water are acidulated with a few drops of dilute hydrochloric acid, a few grammes of the zinc-copper couple are placed in it, and the whole maintained at 37° C. for at least one hour. At the end of this period transfer the contents of the flask to the distillation apparatus as employed in the determination of the free ammonia, add 250 c.cs. of ammonia-free water, and about 2 grammes of recently ignited sodium carbonate, and distil. Determine the amount of ammonia evolved by means of Nessler solution.

From the figure obtained, deduct the free ammonia as found in 100 c.cs. of the water, and any nitrogen due to the presence of nitrites. The remaining figure for ammonia is calculated as nitrogen and recorded as nitric nitrogen.

Note : Care must be taken when transferring the reduced sample to the distillation flask to ensure that no particles of the zinc-copper couple find their way into the distillation flask.

Oxygen Absorbed

This figure is a measure of the amount of organic matter which can be oxidised by permanganate of potash in a given period. The usual periods are 15 minutes and 4 hours. 250 c.cs. of " organic-free "* distilled water for the blank, and two separate quantities of 250 c.cs. each of the sample, are placed in 500 c.c. flasks, previously rinsed with concentrated sulphuric acid to ensure the absence of any oxidisable organic matter. The flasks are then transferred to a thermostat at 27° C. for

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* *Distilled Water free from Organic Matter.*—It sometimes happens that the laboratory supply of distilled water contains traces of organic matter. It is necessary to use water entirely free from organic matter for the oxygen absorbed test. It can be prepared as follows :—

About 0·2 gramme potassium permanganate and 1·0 gramme of potassium hydroxide are placed in two litres of water, the flask being connected with a reflux condenser. Boiling is permitted to continue for about 24 hours, the flask is then fitted to a condenser and the distillate rejected so long as it gives a positive reaction for ammonia with Nessler solution. When free from ammonia it is collected in a clean bottle, and reserved solely for the purpose of the oxygen absorbed test.

a period of 30 minutes, so that the water may be at that temperature when the permanganate is added.   Remove the flasks from the thermostat, and add to them 10 c.cs. of the permanganate solution, which must be accurately measured.   This is followed by 10 c.cs. of the dilute sulphuric acid (1 in 3 by volume), and the flasks, loosely stoppered, are replaced in the thermostat.   At the end of 15 minutes, the blank and one of the flasks containing the sample are removed, and 2 c.cs. of a 10 per cent. solution of potassium iodide are at once added.   The remaining flask is held at 27° C. for a period of 4 hours, at the end of which time a similar quantity of potassium iodide solution is added to it. The iodine thus liberated is determined by titration with sodium thiosulphate solution (1 gramme per 1,000 c.cs. water).   The difference in the figure given by the blank and by the samples depends upon the amount of permanganate taken up by the water, every c.c. of permanganate being equivalent to 0·0001 gramme available oxygen. The permanganate solution is made by dissolving 0·395 grammes in 1 litre of water.

If x represents the number of c.cs. of thiosulphate used in the titration of the blank, y the number of c.cs. used in the titration of the permanganate left in the water under examination, and a the amount of available oxygen in the permanganate, then $\dfrac{(x - y)a}{x}$ will be the weight of oxygen required to oxidise the matter in 250 c.cs. of the water.

Chloride

Measure 50 c.cs. of the sample into a white porcelain basin, and add thereto a few drops of potassium chromate solution.   Run in a quantity of the standard silver nitrate solution until the colour just changes to pink.   Each c.c. of silver nitrate solution is equivalent to 1·0 part of chlorine per 100,000 parts of the water.

Silver nitrate solution.   Dissolve 2·3944 grammes of A.R. silver nitrate in one litre of water.

Interpretation of the Analyses

The interpretation of the results obtained by the examination of water usually calls for a considerable amount of experience, since no definite standards can be laid down upon which an opinion may be based.   Little or no difficulty is met with in instances where the water is of a high degree of purity or is grossly polluted ; in either event the data obtained are sufficiently positive to permit of the water being placed in one of the two classes.   Far more frequently the figures obtained indicate that the water suffers from one or more disadvantages, the sum of which may place it in an unsuitable category for both manufacturing and potable purposes.   It is perhaps desirable to lay stress upon the fact that a water

should not be passed as suitable for a food factory unless it is free from evidence of pollution. Although it may satisfy the requirements from this aspect, there is a possibility that its mineral constituents may be such as to render it unsuitable for canning, etc. For this reason attention must also be directed to the nature of the inorganic salts it may hold in solution. Due consideration will subsequently be given to this point, but as potability is of prime importance, it must be placed first.

In arriving at a decision, the analyst must base his judgment upon both the bacteriological and chemical " pictures " which he has obtained as the result of his examination of the sample. It is also very helpful if he has some knowledge of the source of the water, so that he may know whether it comes from an upland surface, a deep well, shallow wells, a stream, etc. If it is a well water, information as to the well's depth, and the geological strata in its immediate vicinity, is all useful in helping him to draw the correct conclusions.

Free and Saline Ammonia

The amount of ammonia found in waters shows great variation. In upland surface water it seldom exceeds 0·007 parts ; in deep wells it may vary from a minute trace to as much as 0·1 parts per 100,000. In water from cultivated land, amounts from 0·005 to 0·025 may be found. In shallow well waters, the relatively enormous amount of even 2 to 3 parts may be present. Spring waters also show considerable variation, but as a rule not more than 0·01 parts occur. The presence of ammonia in upland surface water is almost invariably due to absorption of this gas from the atmosphere by falling rain and snow, and is always heaviest during the earliest part of the fall. In deep wells, provided there is an absence of other evidence of contamination, the presence of large amounts of free ammonia is not unduly significant, because it may quite probably be formed as the result of reduction of nitrates, brought about by the action of the strata through which the water has passed. Therefore, the presence of even as much as 0·1 parts per 100,000 parts of the water from a deep well must not of necessity be regarded as suspicious.

In water from cultivated lands, the presence of more than 0·008 parts is usually accompanied by some albuminoid ammonia and other chemical evidence of organic impurity ; this amount in such waters is frequently a pointer to pollution with animal excreta. In shallow wells, which are little more than drainage holes for surface water, and seldom unpolluted—usually being in the neighbourhood of dwellings—the presence of a high amount of ammonia is to be expected, and can almost certainly be attributed to the polluted condition of the water, although it is seldom safe to condemn a water solely upon the free and saline ammonia content. Too much importance should not be attached to the amount of this substance found in a water, unless there is other evidence to the effect

that it is due to the presence of human or animal excreta. Ammonia may be present in the stagnant waters supporting confervoid growths, as a by-product of the reduction of nitrate by various organisms. Ammonia formed by reduction is not of frequent occurrence in well waters, unless it is accompanied by ammonia resulting from putrefaction.[5]

Albuminoid Ammonia

This term is apt to be misleading because this ammonia does not exist in waters, but is produced in the laboratory by the action of alkaline permanganate upon the nitrogenous organic matter present in the water. It is now generally agreed that there is a varying relation between the amounts of albuminoid ammonia and the amounts of different kinds of nitrogenous matter present in the water, so that the figure can at best be regarded as a useful indication of the quantity of nitrogenous organic matter with which the water is contaminated.

Wanklyn's standards for albuminoid ammonia are : In water of high purity, albuminoid ammonia does not exceed 0·004 parts per 100,000 ; in water of average purity it does not exceed 0·008 ; in impure water it exceeds 0·008.

In arriving at these " standards," consideration has to be given to the amount of free and saline ammonia present. If this is more than a trace, then albuminoid ammonia to an amount of 0·008 parts must be regarded as a very disquieting feature. Wanklyn does not condemn a water in the absence of free ammonia unless the albuminoid ammonia exceeds 0·0082, but if it shows 0·0123 parts he condemns in all cases.[4, 6] As sewage almost always contains more free and saline than albuminoid ammonia, it may be generally inferred that a water showing low free ammonia and high albuminoid ammonia is suffering from contamination with vegetable matter ; but if the water shows high free ammonia and high albuminoid ammonia, the inference is that the source of contamination is either animal manure or human excreta. These facts can quite often be confirmed by the presence or otherwise of *B. coli* found in bacteriological examination.

Nitrous Nitrogen (Nitrites)

The presence of nitrites in water, even to the extent of a trace, must be regarded with suspicion, unless they are known to come from an innocuous source. Nitrite may be looked upon as the incompletely oxidised organic nitrogenous matter, and indicates that the organic matter is undergoing oxidation, but that the process is not complete, and therefore the contaminating sewage is still in an actively dangerous state. The possibility of nitrites being derived from some other source than sewage must not be ignored, for it has been shown[4] that metallic pipes may bring about the reduction of nitrates to nitrites. Further, in

deep well water, the nitrates may be reduced to nitrites by the action of the strata through which the water has passed. In shallow well waters, or in water from a stream, the presence of nitrite in any amount is to be regarded as definite evidence of pollution.

Nitric Nitrogen (Nitrates)

It is probable that nearly the whole of the nitrates found in water has arisen as the result of the oxidation of nitrogenous organic matter of animal origin, for generally speaking vegetable matter by natural processes of oxidation yields little nitrate whilst animal matter yields much. The amount of nitric nitrogen in waters varies very greatly. In upland surface waters it is usually nil or at the most 0·05 parts per 100,000 parts of the water, but in water from cultivated land and springs it may be anything from nil to 1·5 parts. In shallow well waters it is almost always high, reaching even as much as 20 parts per 100,000 in some cases, but even in this class of water occasionally none is found.

The presence of nitrates is significant because it furnishes an indication of the past history of the water ; when high, the obvious inference is that at some time the water was highly polluted with nitrogenous organic matter of animal origin, probably manure or sewage, which owing to some natural process through which the water has passed, has become oxidised to nitrates. If for any reason this natural oxidation process should fail, then the water would be likely to become unfit for potable purposes, for the polluting agent would have remained in an active form. In certain strata rich in the remains of marine animal life in the form of fossils, such as chalk, the presence of a high amount of nitrate may possibly be accounted for by the water having come into contact with such material. As nitric nitrogen is to be regarded as a pointer to past pollution, as distinct from nitrite as an indication of active pollution, a water containing much of the former cannot be condemned, because any danger which might arise from its consumption has passed. It does, however, show that such a water should be subjected to frequent examination, for if oxidation failed the water might at once become a source of danger.

The fact that quite a number of bacteria will reduce nitrates to nitrogen must not be overlooked, and for this reason a water containing neither nitrites nor nitrates may not necessarily be unpolluted. It is here again that a knowledge of the bacterial flora may be of great assistance.

Oxygen Absorbed by Organic Matter

The permanganate process may be regarded as furnishing an indication of the amount of organic impurity in the water, although the fact must not be ignored that certain inorganic salts, such as ferrous salts, sulphides, etc., will reduce permanganate. These inorganic substances usually act

very quickly, while organic matter takes a much greater length of time to become oxidised. It will be remembered that the test is carried out upon two portions of the water. The first is completed at the end of 15 minutes, the second is allowed to proceed for four hours. If the uptake of oxygen in both tests is practically identical, it is probable that the reaction is due to the presence of inorganic reducing substances. If, on the other hand, the four-hour test shows a greater degree of oxygen absorption than does the 15-minute test, the inference is that the reducing action is to be attributed to organic matter.

Too much importance must not be attached to this figure, for at best it can only be regarded as an index of the relative freedom or otherwise from oxidisable matter of a water ; but, in general, very pure waters absorb none or very little oxygen, while impure waters show a high absorption.

Frankland and Tidy suggest the following classification :

Water of great purity - -	0 to 0·05	parts per 100,000.	
,, ,, average purity -	0·1 to 0·3	,, ,, ,,	
,, ,, doubtful purity -	0·3 to 0·4	,, ,, ,,	
Impure water - - - - -	above 0·4	,, ,, ,,	

Chlorine

Chlorine may be derived from the soil, particularly in places in proximity to the sea-shore from chalky strata, and in some cases from the presence of pockets of salt, the remains of marine deposits. If its presence cannot be attributed to any of these causes, it is very probably due to contamination of the water with sewage or manure, and in such instances must be regarded as an undesirable feature, provided that it exceeds 2·5 parts per 100,000 parts of the water, and there is evidence of the presence of organic matter.

Hardness

Clark's method, employing soap-solution of known strength, while sufficiently accurate for a number of purposes, is not to be recommended for use where more exact data is desirable, as in the case of the mineral analysis of a water. Reliable figures can be obtained by using the method devised by Hehner, which is as follows :

Add to 500 c.cs. of the water—or less if it is likely to be very hard—a few drops of methyl orange solution. Titrate with N /50 sulphuric acid until the colour just changes to pink. The number of c.cs. of acid used, multiplied by 0·0025 and by 200, will give parts per 100,000 calcium carbonate, and represents temporary hardness.

The permanent hardness is determined by taking 250 c.cs. of the water, adding to it 50 c.cs. of N /10 sodium carbonate solution, and then boiling for about 30 minutes. If magnesium salts are present, evaporate to

dryness, and extract the residue with water.   In both cases filter, wash the precipitate with hot water, previously boiled to remove carbon dioxide, cool and filtrate, and make up to 250 c.cs.   Titrate 50 c.cs. of the filtrate with either N/10 or N/50 sulphuric acid.   From the number of c.cs. of acid used, the weight of sodium carbonate taken up in precipitating the hardening salts may be found, and from this figure the permanent hardness is calculated in terms of calcium carbonate.   As these two figures, the temporary and permanent hardness, serve as a check upon certain of the mineral salts found by direct analysis, it is desirable for them to be determined as accurately as possible, and therefore the use of standard acid as described above, rather than standard soap solution, is strongly recommended.

N/10 sodium carbonate is prepared by dissolving 5·305 grammes of *dry* A.R. sodium carbonate in 1 litre of distilled water.   If there is any doubt about the dryness of the reagent, it should be heated in the hot-air oven for at least one hour, just prior to use.   N/10 sulphuric acid may be made by diluting 100 c.cs. of N/1 sulphuric acid to 1 litre.

Methyl Orange Solution.   Dissolve one gramme of the substance in a small quantity of 90 per cent. alcohol, and dilute the solution to 1 litre with equal quantities of 90 per cent. alcohol and water.

Hardness by Soap Solution

The method of determining hardness by soap solution, while not giving such accurate results as that already described, based upon titration of the hardening salts by standard acid, has the advantage of rapidity, and for many purposes the data obtained are a sufficiently close approximation.

The results obtained can be expressed either in parts per 100,000 of the water, or in grains per gallon.   In the former method the standard soap solution is made up according to Clark's formula, and in the latter according to that of Wanklyn.   It is usual to express the result in parts of calcium carbonate per 100,000 parts of the water, when potable waters are concerned, and in grains per gallon when boiler feed waters are being dealt with.

The standard solutions required are as follows :

Standard Calcium Chloride Solution, for Clark's Formula.   Take 0·2 gramme of pure powdered Iceland spar, place in a beaker, and add a small quantity of dilute hydrochloric acid, taking care to prevent loss by spurting.   Continue the addition of the dilute acid until the Iceland spar is all dissolved.   Evaporate the solution to dryness on the water bath, add water, and again evaporate to dryness ; repeat this process twice in order to remove all free acid.   Dissolve residue in distilled water, and make volume up to 1 litre.

Standard Calcium Chloride, for Wanklyn's Formula. Dissolve 1 gramme of powdered pure Iceland spar in dilute hydrochloric acid, taking the precautions and following the method described above ; make the solution up to a volume of 1 litre.

Standard Soap Solution (Clark's Formula). There are several methods for the preparation of this solution. One of the most satisfactory is the following :

One hundred and fifty grammes of lead plaster (Plumbi Emplast B.P.) are rubbed in a mortar with 40 grammes dry potassium carbonate. A small quantity of methylated spirit (free from petroleum) is added, and the mixing continued until a thick cream is formed. More spirit is added, and the mixture stirred, its volume being increased to about 400 c.cs. It is then allowed to settle, and the clear supernatant liquor decanted off from the sediment. The soap has now to be diluted until 50 c.cs. of the standard calcium chloride solution require 14·25 c.cs. of the soap solution. The dilution is carried out by the use of a mixture of equal parts distilled water and methylated spirit.

Measure 50 c.cs. of the calcium chloride into a stoppered bottle of about 250 c.cs. capacity, and titrate it with the soap solution, adding not more than 1 c.c at a time, and shaking vigorously after every addition. When the formation of a lather begins, add the soap solution more gradually—about 0·2 c.c. at each addition—and place the bottle upon its side on the bench. The process is complete when the lather remains unbroken for a period of five minutes.

The strength of the soap solution is likely to undergo a change during the first twenty-four hours after it is made, as a sediment usually forms. The final titration should not, therefore, be made until at least that period of time has elapsed.

The determination of the hardness by the use of soap solution of this strength, using 50 c.cs. of the water under examination, will give the data in parts of calcium carbonate per 100,000 parts of water, the results being read from the accompanying Table I.

For the convenience of those who have to deal with both potable waters and boiler feed waters, and who prefer to keep only one standard soap solution (Clark's), Table II is shown, giving readings in grains per gallon per c.c. of Clark's soap solution.

Standard Soap Solution (Wanklyn's Formula). Prepare the strong soap solution by the method described under Clark's formula, and adopt the same precautions when conducting the titration. Take 20 c.cs. of the Wanklyn calcium chloride solution, place it in a stoppered bottle of about 250 c.cs. capacity, add 50 c.cs. of freshly boiled and cooled distilled water, and continue the addition of the soap until a lather lasting for two minutes has been produced. Adjust the strength of the soap solution until 21 c.cs. are required to produce a similar lather with 20 c.cs. of the

calcium chloride solution, to which has been added 50 c.cs. of distilled water.

Procedure for Clark's Solution

(*a*) *Total Hardness*.   Into a stoppered bottle of 250 c.cs. capacity, measure 50 c.cs. of the sample of water.   Shake the bottle, and remove any CO_2 which has been given off by the water, by sucking out the air from the bottle by means of a pipette.   Then proceed to titrate in the manner described under the preparation of the standard soap solution.   If more than $16 \cdot 0$ c.cs. of soap solution are required by the sample, dilute a suitable measured quantity of the water to a volume of 50 c.cs. with freshly boiled and cooled distilled water.   Make the necessary correction for volume when referring to the table of hardness.

(*b*) *Permanent Hardness*.   Measure 100 c.cs. of the sample into a beaker, and proceed to boil until the volume is reduced to at least 50 c.cs. This may be determined approximately by marking the beaker at a point showing rather less than half the depth of the water.   When the operation of boiling is completed, transfer the residual water to a filter, allowing filtrate to flow into a 100 c.c. flask.   Cool, make up the volume to 100 c.cs., shake, measure 50 c.cs. into the bottle used for the hardness titration, and titrate with soap solution in the described manner.   The 50 c.cs. titrated is equivalent to 50 c.cs. of the original sample.   From the number of c.cs. of soap solution required, the hardness is found by referring to the table.   The figure for total hardness, less that for the permanent hardness, gives the temporary hardness.

Procedure for Wanklyn's Solution

Total Hardness.   Measure 70 c.cs. of the water into a stoppered bottle of 250 c.c. capacity, and titrate, with the precautions mentioned above, until a lather is produced which will remain without breaking for two minutes.   The number of c.cs. of Wanklyn's soap solution required, less 1 c.c (the amount required for 70 c.cs. distilled water), will give grains per gallon of total hardness.

The method employed for the determination of the permanent hardness is similar to that described under Clark's solution, except that 140 c.cs. of the water are taken and concentrated to approximately 70 c.cs.

Mineral Analysis

In addition to these determinations, there are others that help to fill in the picture of the water.   They are as follows :

Free Carbon Dioxide

It is desirable to make this determination immediately the sample bottle is opened. Titrate 100 c.cs. of the water with standard sodium carbonate solution, using phenol phthalein solution as an indicator, until a faint permanent pink colour is produced. Avoid any unnecessary agitation of the flask.

The sodium carbonate solution is made by dissolving 3·446 grammes of *dry* A.R. sodium carbonate in 1 litre of freshly boiled and rapidly cooled distilled water.

To make phenol phthalein solution, dissolve 0·2 gramme of the substance in 60 c.cs. of 90 per cent. alcohol, and make up volume to 100 c.cs. with distilled water.

The number of c.cs. sodium carbonate solution required by the sample, less that needed by 100 c.cs. of freshly boiled and rapidly cooled distilled water, will give the amount of free carbon dioxide in the water in grains per gallon. The figure may be converted into parts per 100,000 by dividing by 0·7.

Silica, Calcium and Magnesium

Take 250 c.cs. of the water, place this in a beaker of about 400 c.cs. capacity, add a few c.cs. of concentrated hydrochloric acid, and evaporate to dryness. When the volume has been reduced to about 20 c.cs., complete the evaporation on a gently heated sand bath, being careful to avoid spurting. Leave the dried solids in the beaker upon the sand bath, the temperature of which may be raised, so as to char any organic matter present. If treated with caution, the beaker will withstand this heating without cracking. Allow to cool; then add 10 c.cs. of hydrochloric acid and about 10 to 15 c.cs. water. Boil, and filter through a rapid and ashless filter paper, carefully washing the precipitated silica from the sides of the beaker. Wash with hot water. The filtrate and washings, which should not exceed 50 c.cs. in volume, contain the calcium, magnesium, iron, aluminium, and manganese. The precipitate consists of silica, which may be dried, ignited and weighed in the usual manner.

Quite often the amount of silica in the water is either nil or too small to determine, unless a much larger volume of water than 250 c.cs. is taken. In such examples it is unlikely to be of significance in regard to cannery water.

To the filtrate from the silica, which should be about 50 c.cs. in volume, add 1 c.c of bromine water, warm, then add strong ammonia until the colour of the bromine is destroyed, and a slight excess of ammonia remains. Heat to boiling, and allow to stand for a few minutes in order that the precipitate may coagulate. Filter, and wash the precipitate four times with hot distilled water. The precipitate consists of iron, aluminium and manganese. It is usually small in volume, and it is not

always necessary to determine the constituents separately. If so, the precipitate is ignited and weighed, the result being expressed as iron, aluminium and manganese. As, however, the amount of iron present in a water is of considerable importance to the manufacturer of canned food, it is usually necessary to determine accurately the quantity present. As it is likely to be small, a colorimetric method should be employed.

Iron by the Thiocyanate Method

The following solutions are required :

Standard solution of iron (ferric). Dissolve 0·7022 gramme of A.R. ferrous ammonium sulphate in distilled water, add about 3 c.cs. of dilute sulphuric acid (1 : 3 by volume) and then cautiously add a dilute solution of potassium permanganate (2·5 grammes per litre) until a slight pink colour remains. Dilute to one litre. 1 c.c of this solution is equivalent to 0·0001 gramme of iron.

Potassium or ammonium thiocyanate solution. A 7·5 per cent. solution in water.

Procedure. Evaporate 100 c.cs. of the water to dryness in a platinum dish, and when dry ignite gently to remove organic matter. Take up the residue in dilute nitric acid, about 5 per cent. by volume, using not more than 2 or 3 c.cs. Evaporate to dryness on the water bath, and dissolve the residue in 2 or 3 c.cs. of dilute hydrochloric acid ; add about 20 c.cs. water, filter, and wash the precipitate with water. Make up the filtrate to 50 c.cs. in a Nessler glass, and add 2 c.cs. of the thiocyanate solution. Match the colour produced by making various dilutions of the standard iron (ferric) solution, and calculate the quantity of iron present in the water, expressing the result in parts per 100,000. The test is sensitive to 1 part of iron in 50,000,000.[6]

Iron by Thioglycollic Acid $(CH_2SH.COOH)$[7]

This reagent produces, in the presence of ammonia, a purple colour with a trace of ferrous or ferric iron. 5 c.cs. of the aqueous solution containing the iron are treated with one drop of the thioglycollic acid, and 0·5 c.c. of 0·880 ammonia. The colour produced is then compared with that formed by various dilutions of the standard iron solution. The test is stated to be sensitive to 1 part of ferrous or ferric iron in 5 million parts of the water. The method possesses the advantage over the thiocyanate method in that the water need not be evaporated to dryness and therefore time is saved in making the determination.

Iron by the Ferrocyanide Method

The procedure is precisely similar to that employed in the thiocyanate method, except that 1 c.c of a 5 per cent. solution of potassium ferro-

cyanide is used in place of the thiocyanate, and care must be taken to make certain that the reaction takes place in the presence of acid. The method possesses no advantages over the thiocyanate one.

Manganese

The following method[4] is quite satisfactory:

To 100 c.cs. of the water add 1 drop of concentrated nitric acid, and dilute silver nitrate solution in slight excess of that required to precipitate the chlorides. Raise to boiling point and filter. To the filtrate add 2 grammes of potassium persulphate and boil for ten minutes. In the presence of manganese a pink colour is produced, and the quantity of manganese present can be determined by comparing the colour with various dilutions of standard permanganate solution. (The standard used for the determination of oxygen absorbed may be used after dilution.)

Alumina

Ignite and weigh the precipitate produced by the addition of ammonia to the oxidised hydrochloric acid solution, after the removal of the silica. Deduct from the weight obtained the iron and manganese (if any) as determined above, calculating the figures to oxides. The difference is alumina.

There are two alternative methods for the analysis of aluminium directly, one using 8-hydroxyquinoline, and the other aurin tricarboxylic acid.

Method using 8-*hydroxyquinoline.* Care must be taken that the solution is completely free from iron. It should contain not more than the equivalent of 0.1 gm. Al_2O_3. One or two drops of mineral acid per 100 c.cs. are added, the solution heated to about 70° C., and an excess of the reagent added. The reagent is made by dissolving 25 gms. of 8-hydroxyquinoline in 60 c.cs. of glacial acetic acid. This is diluted in cold water to two litres. To the solution under test 2N ammonium acetate solution is added until a permanent precipitate is formed, 20 to 25 c.cs. more are then added, the precipitate is allowed to settle, filtered through a weighed Gooch crucible. Wash with cold water, dry at 120° to 140°, and weigh as $Al(C_9H_6ON)_3$ containing 11.1 per cent. of Al_2O_3.

Aurin tricarboxylic acid. With this aluminium forms a red lake, and the test can be made the basis of a colorimetric determination by comparison with the colour obtained from solutions containing known quantities of aluminium.

Calcium

The filtrate from the iron and alumina precipitate is heated upon the water bath, and a few crystals of ammonium oxalate are added, the beaker being gently agitated during the addition. Settlement of the

precipitate is hastened by gently boiling the contents for a few minutes, but not for a sufficient length of time to remove all the excess of ammonia. Allow to stand, and, when the precipitate of calcium oxalate has settled, add a drop of ammonium oxalate solution to ensure that all the calcium has been thrown down. Filter, and wash several times with successive quantities of hot water. The precipitate may either be ignited strongly over a blow-pipe flame and weighed as CaO, or, having been washed free from excess of oxalate (which can be ascertained by testing a few c.cs. of the filtrate in a test-tube with calcium chloride solution—no precipitate should be formed), determined volumetrically by titration with standard potassium permanganate. A hole is then made in the bottom of the filter paper. The contents are washed into a beaker with cold water, care being taken to remove all the precipitated calcium oxalate from the paper. A quantity of concentrated sulphuric acid is then added to the aqueous suspension of calcium oxalate, and, whilst hot, the free oxalic acid produced is titrated with deci-normal potassium permanganate solution, 1 c.c. of which is equivalent to 0·0028 gramme of calcium oxide.

N/10 potassium permanganate is made by dissolving 3·161 grammes of the salt in water, and making the solution up to a volume of 1 litre.

Note.—If the calcium is determined gravimetrically, the precipitate should be re-ignited and re-weighed until its weight is constant.

Magnesium

The filtrate and the first six washings from the calcium oxalate precipitate are transferred to a flask of about 250 c.cs. capacity, a large excess of ammonia added, and then about 5 c.cs. of a saturated solution of sodium hydrogen phosphate. Shake very thoroughly, and allow to stand for 12 hours. If this is not possible, agitation should be continued for 30 minutes, at the end of which period all the magnesium should have been thrown down. Filter, wash with warm ammonia solution until the washings, when acidified with nitric acid, give no precipitate with silver nitrate solution. Ignite the precipitate, use gentle heat at first and then full heat until the whole of the carbon has burnt away. Cool and weigh the precipitate as magnesium pyrophosphate. Multiply the weight obtained by 0·36243 to obtain the weight of magnesium oxide (MgO).

Sodium

This figure is not usually required, but should circumstances make it necessary for it to be determined, the filtrate from the calcium oxalate is made up to a definite volume, and divided into two equal quantities. The first is used for the determination of the magnesium, the second is acidified with hydrochloric acid, and evaporated to dryness in a porcelain basin of ample dimensions, care being taken to prevent the salts from creeping over the edge of the basin. When evaporation is complete,

the dish is gently ignited to drive off the ammonium salts, and the heating must be continued until white fumes cease to be evolved. The weight of the residue is determined as sodium chloride, and calculated to sodium oxide.

Sulphuric Anhydride

Five hundred c.cs. of the sample are acidified with a few drops of hydrochloric acid, and evaporated to a bulk of about 50 c.cs. in a beaker. A few c.cs. of barium chloride solution are added to the boiling liquid, and the precipitate formed allowed to settle, when it is filtered off, washed with hot water until the washings are free from chloride (test with silver nitrate solution), dried, ignited, and weighed as barium sulphate. Multiply the weight obtained by 0·34293, which will give SO_3.

Dissolved Oxygen

It is sometimes necessary to determine the quantity of oxygen in solution, and this can readily and reasonably be accurately carried out as follows :

Two hundred and fifty c.cs. of the water are placed in a stoppered bottle,* and 2 c.cs. of manganous sulphate solution, and a like quantity of potassium iodide solution containing sodium hydroxide, are added, the mouth of the pipette being allowed to dip just below the surface of the liquid. Add 2 c.cs. of dilute sulphuric acid, and mix well. Titrate with N/10 sodium thiosulphate solution, using starch as an indicator towards the end of the reaction. 1 c.c. of the thiosulphate solution, multiplied by 0·056, divided by 0·7, gives parts per 100,000 of dissolved oxygen. The figure is usually calculated as c.cs. per litre.

Carbonates

This has already been carried out during the determination of the temporary hardness by the Hehner method.

It is not possible to ascertain with any degree of certainty in what state of combination the various salts present in a water exist, but some recognised method of calculation is desirable. The following system may be usefully adopted, based upon the solubility of the substances.[8]

All the calcium oxide, or as much as possible (dependent upon the amount of alkalinity) should be calculated as calcium carbonate, any remaining lime as calcium sulphate ; any still remaining as calcium nitrate (if there is sufficient nitrate to allow for this). If there is any excess of calcium, this should be calculated as calcium chloride.

If any alkalinity remains after calculating the calcium carbonate, all the magnesia should be calculated as magnesium carbonate, and any remaining magnesia as sulphate, nitrate and chloride, respectively and

* The capacity of the bottle should be known, and it must be filled with water and reagents.
Manganous sulphate solution : 50 gms. in 100 c.cs. of water.
Alkaline potassium iodide solution : KI, 10 gms. ; KOH, 70 gms. ; water, 100 c.cs.

in the order named. Any remaining alkalinity or acid radicles to be calculated as sodium salts. The silica is calculated as SiO_2. The iron and aluminium as Fe_2O_3 and Al_2O_3 respectively.

Some idea as to whether the calculated figures are probably representative of the true state of combination in the water may be obtained by adding them together and ascertaining if the total approximates to the total solids in solution in the water. A discrepancy of a few parts per 100,000 may be expected, owing to organic matter present in the water, or water of crystallisation not expelled at the temperature used for determining the solids, but a wide variation indicates that the calculated figures have not truly interpreted the state of combinations of the radicles present in the water.

Bacteriological Considerations

It is now generally conceded that an accurate judgment of a water cannot well be made without some knowledge of the bacterial flora which it carries. The complete isolation and identification of all the organisms which may be present in a water is likely to be a long and tedious operation, and it is therefore usual to confine the examination to a determination of the number of *B. coli* organisms present. This may be followed by plating out a sample, making a rough count, and examining the colonies formed to ascertain if micrococci are present to any serious extent.

Not too much weight must be attached to a count, for great variation may be shown by two samples drawn from the same source, dependent upon rainfall, etc. Except with deep wells, heavy rainfall after a prolonged dry spell almost invariably causes a very large increase in the number of bacteria present.

Pure waters, such as those drawn from deep wells or purified by artificial means, seldom show the presence of *B. coli* in 100 c.cs. This should therefore be the state of purity to be aimed for. Where a sample gives a positive test for *B. coli* in quantities of 20 c.cs. or less, there is a definite indication of recent pollution. Waters intermediate between the presence of *B. coli* in 100 c.cs. and absence in 20 c.cs. call for more careful judgment, but in any event, where a water is required for manufacturing purposes the presence of *B. coli* in 50 c.cs. should be looked upon as the maximum which can possibly be permitted, and only then if the picture presented by its chemical examination indicates a reasonable freedom from organic pollution. If this comparatively indifferent standard of purity cannot be attained, then the water must be submitted to artificial treatment.

The three organisms invariably associated with fæcal matter are *B. coli communis*, *streptococci*, and *B. welchii*, this last usually in the form of spores. Of these organisms, *B. coli* is by far the most abundant ; it
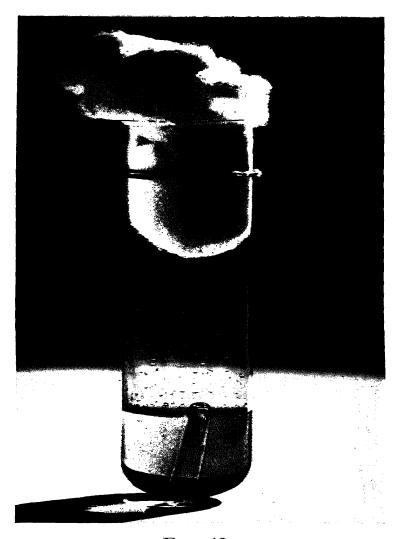
Fig. 42

SMALL DURHAM FERMENTATION TUBE
INSERTED IN LARGE BOILING TUBE CON-
TAINING SOLUTION. THE RUBBER BAND
ROUND THE NECK IS PART OF A SUPPORT
USED FOR PHOTOGRAPHIC PURPOSES

Courtesy of " Food "

[Facing page 118

may vary from 100,000 to 1,000,000 per c.c. ; *streptococci* from 10,000 to 100,000 per c.c. ; and spores of *B. welchii* from 100 to 10,000. It is doubtful if any of these three organisms in themselves can be regarded as pathogenic, but the fact that they show the presence of fæcal matter in the water at once indicates that typhoid fever or other diseases might readily be borne by the water. Therefore, much significance attaches to their presence.

A great amount of thought has been given to the most practicable methods of sorting out these organisms from others existing in a water, and it has now been generally agreed that the most important factor is the presence or otherwise of organisms of the *B. coli* group. The test is dependent upon the fact that organisms of this genus ferment lactose in the presence of bile salt, so that if a sample of water exhibits that characteristic, further examination is needed in order to identify, if possible, the organism of the group causing the fermentation. If the sample of water gives a negative test, then, unless there are other special circumstances to be taken into consideration (such as indication of past heavy pollution as evidenced by the chemical examination), the water may as a rule be passed as fit for potable purposes.

The test is conducted by using lactose-bile-salt litmus peptone solution, prepared as given in Chapter X. The medium thus prepared is then transferred to tubes, after having undergone dilution to various strengths according to the quantity of water likely to be tested. It is usual to prepare the following :

When 50 c.cs. of the water are to be examined, 2 parts of the medium are mixed with 1 part of distilled water and 50 c.cs. of this dilution are placed in a large boiling-tube of at least 130 c.cs. capacity. In this large tube is placed a small Durham fermentation tube—a test-tube about 2 ins. long by ¾ in. diameter (see illustration).

When 20 c.cs. of water are to be tested, run into a test-tube of 50 c.cs. capacity 10 c.cs. of the broth, and again place in the tube a Durham fermentation tube, preferably rather smaller than the one used above.

For 10 c.cs. of the water, use 2 parts of the medium with 1 part distilled water, and put into test-tubes about 6 ins. long by ¾ in. diameter and for 5 c.cs. of the water use the same sized tube as for 10 c.cs., but mix 1 part medium with 1 part distilled water. For 2 c.cs. of the water, use 1 part medium with 1 part water, and place in test-tubes 6 by ⅝ in. In all dilutions insert the Durham fermentation tubes.[4] It is as well to prepare at least six tubes of every dilution, unless the character of the water is well known, when the test over such a large range of volume need not be undertaken. For example, if the water is expected to be of good quality, an examination of 50 and 100 c.cs. will be sufficient.

All the dilutions should be sterilised at 100° C. for 20 minutes on three successive days. It is inadvisable to use higher temperatures when dealing with media containing carbohydrates.

Making the Test

Precautions having been taken in regard to mixing the sample, quantities of 50, 20, 10 and 5 c.cs. are withdrawn by means of sterile pipettes and placed in the tubes of medium; at least three of each dilution should be put up, and incubated for 24 hours at 37° C. When smaller quantities, such as 1 c.c or less, of the water have to be tested, it is desirable to dilute them with sterile distilled water. For example, if 1 c.c is to be examined, 10 c.cs. of the water is diluted to 100 c.cs., and 10 c.cs. of the mixture taken for the test.

After 48 hours' incubation, the tubes are examined for the presence of acid production and gas, with some turbidity. The gas will be observed in the fermentation tube, and a satisfactory test usually shows about 10 per cent. of the volume of the tube to be filled with gas. A positive test here may be regarded as presumptive for the presence of B. coli. Suppose that the 5 c.c. and 10 c.c. tubes show a negative result, but the 20 c.c and the 50 c.c. positive results, then the test indicates that organisms of the B. coli group are present in 20 c.cs. of the water. Unless two out of the three tubes of the dilution show a positive result, the test is regarded as negative. The presence of gas in one tube out of three is not generally regarded as constituting a positive result.

It may be noted that some workers use a bile-salt-litmus glucose broth instead of one containing lactose as recommended above. Where a greater knowledge of the fermentative flora present in the water is desired, the use of glucose is to be preferred, but where the presence or absence of organisms of the B. coli group is the chief consideration, lactose should be employed, because it particularly favours the growth of this group.

Lactose fermentation with the production of acid in a bile-salt medium is produced by B. coli comm·unis, and by other organisms of the B. coli group, including B. ærogenes. Assuming, therefore, that the sample under consideration has given a positive presumptive test, the next step is to determine whether the organism present is B. coli communis or one of the other members of the group. Of these, the B. ærogenes sub-group is the most likely to occur because it is an organism which commonly predominates in soils and plants, as distinct from B. coli communis, which is invariably present to an enormous extent in fæces. It should therefore be clearly understood that fermentation of lactose in the presence of bile-salt is not a positive test for B. coli communis. To differentiate between this organism and B. ærogenes, the following technique should be followed:

One or more of the tubes showing acid and gas are plated out upon lactose bile-salt neutral red agar. This medium is prepared as given in Chapter X under the heading Neutral Red Lactose Bile-Salt Medium.

It is desirable to work with two tubes showing the acid and gas

production with the smallest dilution of the water tested, and a separate plate should be made from each tube.

The plates after inoculation should be incubated at 37° C., and a period of 48 hours should be sufficient to produce suitable colonies for " fishing."

On this neutral red, lactose bile-salt medium, *B. coli* grows as red colonies, with a peripheral haze, usually accompanied by a reddening of the surrounding medium. Provided that suitable dilutions have been employed, the colonies of the various organisms should be well separated. The colonies of *B. ærogenes* are quite similar in appearance to *B. coli*, except that they are perhaps rather larger, usually more raised, and show a tendency to coalesce. Some experience is needed to distinguish between the colonies of *B. coli* and *B. ærogenes* at this stage.

Confirmatory Tests

The final confirmatory tests are carried out as follows : It should be noted that the procedure varies in different countries, but the method usually adopted in Great Britain, and recommended by Beale and Suckling[4] as a minimal confirmatory test, is :

Inoculation into lactose broth.

Inoculation into glucose broth for methyl-red reaction and the Voges-Proskœur reaction, which is carried out as follows : The bacteria are grown in glucose broth, at 37° C., and at the conclusion of 70 hours three or four drops of a 10 per cent. solution of potassium hydroxide are added. A red fluorescence slowly appears with certain bacteria, such as *B. lactis ærogenes*, but *B. coli* gives a negative test.

Inoculation into peptone water for indol production and morphological observation.

Inoculation of litmus milk for production of acid and clot.

Inoculation of gelatine.

The preparation of lactose broth is described later in Chapter X.

Application of the Methyl-Red Test. The organism is grown in the glucose broth by incubation at blood heat for two to four days, or longer if necessary ; the methyl-red solution is then added. A distinct red colour is regarded as a positive test, and a yellow colour as a negative test. Occasionally, intermediate colours are obtained, in which case the test must be regarded as inconclusive.

Indol Production. To a culture of the organism in peptone water, 5 or 6 drops of concentrated sulphuric acid are added, followed by 1 c.c. of a 0·02 per cent. solution of sodium nitrite in water. The production of a pink colour indicates the formation of indol, which sometimes appears only slowly.

Litmus Milk Reaction. The tubes are inoculated with the organism, incubated at 37° C. for 24 to 28 hours, and the condition of the milk

noted. Acid production is indicated by the litmus, and clotting by the separation and coagulation of the casein.

To return to the cultures growing upon the lactose bile-salt agar plates, two or three colonies are selected, picked off by means of the fishing needle, and transferred to small tubes containing 1 c.c. of sterile distilled water. One loopful of the dilution thus made is inoculated into the various tubes of media described above. It is advisable also to prepare an agar slant from every colony selected, in case subsequent further study of the organisms should be needed.

An organism giving a positive test with methyl red, a positive indol reaction, and a positive lactose fermentation reaction, but a negative Voges-Proskœur reaction, can be definitely regarded as *B. coli*.

An organism giving a positive Voges-Proskœur reaction, a positive lactose fermentation reaction, a positive or negative indol reaction, and a negative methyl-red rest, is to be considered as belonging to the *B. ærogenes* group.

Both *B. coli* and *B. ærogenes* produce acid and coagulation in litmus milk.

It should be noted that *B. typhosus* produces on neutral red bile-salt-lactose-agar medium, yellowish white colonies, easily distinguished from the red colonies produced by *B. coli* or *B. ærogenes*.

Unless exceptional circumstances exist, a water for canning purposes should show the absence of *B. coli* organisms in 100 c.cs.

It is doubtful if *B. coli* group organisms are ever entirely absent from any water if sufficient of the sample be examined. Freedom from this organism in 100 c.cs. may be regarded as a high standard of purity, but one that should certainly exist in all public water supplies, or in those used in the preparation of food.

The above may be regarded as a rapid practical method for the examination of water for *B. coli* organisms. If fuller details in regard to the bacteriological testing of water are desired, a standard work on bacteriology must be consulted.

Boiler Feed Water

The literature dealing with the treatment of waters for this purpose is voluminous, and it is not possible here to do more than give a brief summary of what is considered to-day to be the best practice. In general, it may be stated that a water should :

(1) Contain only a small amount of solids in solution.

(2) Be alkaline in reaction.

(3) Be free from substances which will exert a corrosive action upon the boiler and its fittings. These include oil or grease. This last condition applies to all boiler feed water, but the amount of solids in solution, and the amount of alkalinity, need not be quite so strictly controlled for boilers

of the Lancashire type as for water-tube boilers, which work at higher pressure.

Modern steam-raising plant usually consists of water-tube boilers, working at pressures anywhere between 220 to 900 lbs. per square inch, with superheaters, economisers, etc., and the various accessories associated therewith. Very high pressures are seldom employed where process steam is required, for its temperature is too high to render it suitable for such purposes. Such high pressures are more often used in large turbine generating stations. In such boilers practically the whole of the steam can be returned to the boiler as condensate, and only about 2 per cent. of " make-up " water is required. In large generating stations the make-up water is prepared by softening the available supply, and then preparing from it distilled water. The result of this treatment is that the total feed water is almost entirely free from soluble matter, and very suitable for the purpose.

In a canning factory, much of the steam generated will be needed for process work, and therefore the amount of make-up water will be large in proportion to the condensate from the turbo-generators, quite likely amounting to 75 per cent. of the total feed water used. Some of this 75 per cent. can occasionally be furnished by utilising the condensate from the cooking vessels, but vigilance must be exercised to ensure that it contains no grease of any sort ; it can easily be picked up from slight jacket leaks or other sources. Grease in a boiler is exceedingly harmful, and must be avoided. The remainder of the make-up water must be drawn from the available source of supply, and will certainly need a softening treatment.

For water-tube boilers working under pressures of about 220 lbs. to the square inch, the make-up water should contain not more than 2 grains per gallon of total hardness, the lowest possible quantity of solids in solution, and an alkalinity of 3·5 to 4 grains per gallon, of which slightly more than half should be due to sodium hydrate.

Base Exchange and Other Methods

The base-exchange or zeolite method of treating water is not be recommended for boiler water, because the reactions taking place convert the temporary and permanent hardening salts into an equivalent weight of soluble sodium salts, which, of course, have the effect of maintaining in the water a relatively high amount of soluble solids. This is especially true where a very hard water is in use. For this reason and also for reasons of economy the lime-soda process is almost invariably employed, for it throws out of solution practically all the hardening salts, without the formation of an equivalent weight of soluble salts, although the removal of the permanent hardness results in the production of an equivalent weight of sodium sulphate.

For a detailed description of the lime-soda process, the reader is referred to works dealing specially with the subject. The principle is the addition of sufficient calcium hydrate and sodium carbonate to remove both the temporary and permanent hardness and to impart the desired alkalinity. The reactions upon which the process depends are as follows :

<div align="center">

TEMPORARY HARDNESS

</div>

$$CaH_2(CO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$$
$$MgH_2(CO_3)_2 + 2Ca(OH)_2 = 2CaCO_3 + Mg(OH)_2 + 2H_2O$$

<div align="center">

PERMANENT HARDNESS

</div>

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$
$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl$$
$$Ca(NO_3)_2 + Na_2CO_3 = CaCO_3 + 2NaNO_3$$
$$MgSO_4 + Ca(OH)_2 = Mg(OH)_2 + CaSO_4$$
$$MgCl_2 + Ca(OH)_2 = Mg(OH)_2 + CaCl_2$$
$$Mg(NO_3)_2 + Ca(OH)_2 = Mg(OH)_2 + Ca(NO_3)_2$$

It will be observed from the equations that twice as much lime is required to remove magnesium bicarbonate as to remove calcium bicarbonate. It has also been found that a much longer contact period is needed when dealing with a water containing a considerable proportion of magnesium salts. This disadvantage may be overcome by the addition of a small amount of sodium aluminate, usually not more than 3 or 4 grains per gallon. This salt serves as a coagulant, and a flocculant hastening the precipitation of magnesium hydrate, and also assisting filtration. It has also been shown that sodium aluminate forms an insoluble double salt with silica, and this reagent may therefore be used for the removal of that substance from boiler feed water, as well as assisting in the precipitation of the magnesium salts.

Sodium Phosphate Method

More recently sodium phosphate (Na_3PO_4) has come into use for treating water intended for high-pressure boilers. Its purpose is firstly to prevent the formation of hard scale if any calcium sulphate finds its way into the boiler, and secondly to mitigate the danger of caustic embrittlement of the boiler plates. Sodium carbonate under ordinary conditions of temperature would serve the same purpose, but at high pressures and temperatures it breaks up into sodium hydrate and carbon dioxide. The sodium hydrate reacts with the calcium sulphate to form calcium hydrate, which will produce lime scale. The phosphate, on the other hand, reacts to form calcium phosphate, which is not considered to be a scale-producing salt; it forms a sludge which can be removed with the blow-down water. The reaction taking place with calcium sulphate is as follows :

$$3CaSO_4 + 2Na_3PO_4 \cdot 12H_2O = Ca_3(PO_4)_2 + 3Na_2SO_4 + 24H_2O.$$

The sodium phosphate may be added to the feed water after softening, or it can be placed in the boiler prior to the beginning of a run. In either instance the quantity present should not be allowed to exceed 0·5 grain per gallon. A rapid disappearance of the phosphate in the boiler water indicates that an undue quantity of hardening salts is finding its way into the boiler. Considerable attention has recently been directed to the amount of sodium sulphate considered desirable in boiler water. It has been found that in high-pressure water-tube boilers the ratio of sodium sulphate to total alkalinity due to sodium salts should not be less than 2 to 1 for boilers operating at pressures up to 250 lbs. per square inch.

Control of Sodium Chloride

An examination of boiler water will usually show that most of the soluble solids consist of sodium sulphate and sodium chloride. The amount of this latter salt will be dependent upon the quantity present in the feed water, and as there is no commercial method whereby it can be removed, its concentration in the boiler water can be controlled only by the necessary amount of blowing down of the boiler.

The presence of dissolved oxygen in the feed water is also an undesirable feature, and if it is found to exceed 0·5 c.c. per litre after the water is treated and mixed with the turbine concentrate, then the softened water should be heated prior to its entrance to the boiler. In modern plants this is carried out by the economiser.

To sum up, the suitable conditions of a feed water for use in a water-tube boiler, consisting of a mixture of condensate and softened water, are that the dissolved oxygen should not be more than 0·5 c.c. per litre, and the sodium chloride not more than 0·5 grain per gallon. Caustic alkalinity should be at least 2·0 grains, but not more than 2·75 grains, and hardness not over 2 grains per gallon.

Suitable Boiler Water

The suitable conditions of the boiler water should be : caustic alkalinity (NaOH + Na_2CO_3) not exceeding 50 grains per gallon ; total solids not exceeding 500 grains per gallon, of which not more than 50 grains are sodium chloride. (This last stipulation is difficult to maintain in practice.)

The ratio of sulphate to alkalinity should be 2 : 1.

Special requirements are called for when high pressures are employed, but as these seldom obtain where process steam amounts to a considerable proportion of the total generated, they will not be discussed.

Where boilers of the Lancashire type are used, and turbines are not employed, pressures up to 180 lbs. per square inch are commonly found. As a general rule the conditions called for in the feed water are not so

exacting, since the formation of a small quantity of scale is much less harmful. Higher concentration of the water is unlikely to interfere with the working conditions, priming being less probable. Opinions differ regarding the maximum amount of concentration permissible, figures as high as 7,000 grains per gallon being sometimes quoted. However, experience has shown that 800 to 1,000 grains is a much safer figure to work to. The feed water, which will contain no make-up water, may contain up to 2·5 grains per gallon of hardness and 3·5 to 4 grains of caustic alkalinity. The alkalinity of the boiler water should not be allowed to exceed 50 grains per gallon.

Alkalinity

Fifty c.cs. of the water are placed in a flask, and 3 or 4 drops of phenol phthalein are added. The water is then titrated with N/50 sulphuric acid until a permanent faint pink colour is produced.

The acid used will have neutralised all the hydrate and half the sodium carbonate present in the 50 c.cs. of water, since the colour of phenol phthalein is destroyed by free carbon dioxide.

A further 50 c.cs. of the water is taken, and barium chloride solution added in excess. This reagent removes the carbonate as barium carbonate, which is filtered off. The precipitate is washed once or twice with distilled water, and the washings, together with the filtrate, titrated with N/50 sulphuric acid, using phenol phthalein as an indicator. The number of c.cs. of N/50 acid required will give a measure of the total hydrate present in the water. If the number of c.cs. needed be deducted from the number required for the first titration, the difference will be the number of c.cs. required for half the carbonate. This figure is therefore doubled and multiplied by 0·00106 (1 c.c. N/50 sulphuric acid is equivalent to 0·00106 gms. sodium carbonate). The number of c.cs. required for the determination of the hydrate is multiplied by 0·0008 (1 c.c. of N/50 sulphuric acid is equivalent to 0·0008 gms. sodium hydrate).

Example : In a particular case 50 c.cs. of the water required 2·2 c.cs. N/50 sulphuric acid, and the second 50 c.cs. (after precipitation of the carbonate with barium chloride) required 1·5 c.cs. N/50 sulphuric acid.

Sodium carbonate present : $(2·2 - 1·5) \times 2 \times 0·00106 \times 2 \times 1000 =$ 2·968 parts per 100,000 or 2·0776 grains per gallon sodium carbonate.

Sodium hydrate present : $1·5 \times 0·0008 \times 2 \times 1000 = 2·4$ parts sodium hydrate per 100,000 or 1·68 grains per gallon.

Routine Test

It frequently happens that the routine testing of feed water has to be carried out by other than a skilled chemist, and in situations where it is inconvenient to house more than the minimum quantity of chemical apparatus. Under such conditions the method described for the determina-

tion of alkalinity is somewhat cumbersome. In such cases, use may be made of a special indicator, which in alkaline solution gives a purple colour, changing to blue when the hydrate is neutralised, and to yellow when the carbonate is neutralised.

Seventy c.cs. of the water are placed in a flask and a few drops of the indicator added ; the sample is then titrated with N/50 sulphuric acid until the colour just changes to blue, at which stage the number of c.cs. required is noted. The addition of the acid is then continued until the blue colour changes to a definite yellow, when the number of c.cs. of acid is again noted. The first figure is the number of c.cs. of acid required to neutralise all the hydrate alkalinity and half the sodium carbonate. The second titration (colour change from blue to yellow) indicates the amount of c.cs. of acid required to neutralise the remaining half of the carbonate.

Calculation. (a) From the first figure obtained deduct the second figure and multiply the difference by 0·8 = grains per gallon of sodium hydrate.

(b) Double the second figure and multiply the product by 1·06 = grains per gallon sodium carbonate.

The special indicator may be made as follows :

(a) 0·6 gm. *ortho*-cresol phthalein in 100 c.cs. of 90 per cent. alcohol.

(b) 0·6 gm. bromo-thymol-blue in 100 c.cs. 50 per cent. alcohol.

Mix four volumes of (a) with one volume of (b).

Determination of Sodium Phosphate

As the quantity present is likely to be very small, it is best determined colorimetrically, by the method which depends upon the fact that hydroquinone in the presence of ammonium molybdate yields with a phosphate a blue colour, the depth of which is dependent upon the amount of phosphate present.[9]

Reagents required are 5 per cent. solution of ammonium molybdate in 5N sulphuric acid, a 20 per cent. aqueous solution of sodium sulphite in water ; 0·5 per cent. aqueous solution of hydroquinone containing 1 c.c. normal sulphuric acid per 100 c.cs.

Seventy c.cs. of the water are placed in a Nessler glass, 4 c.cs. of the ammonium molybdate solution, 2 c.cs. of the sodium sulphite solution and 2 c.cs. of the hydroquinone solution are added and mixed ; the mixture is allowed to stand for 30 minutes, at the end of which time the colour will have reached a maximum intensity. This colour can be matched with the required quantity of a standard solution of sodium phosphate containing 1·0 grains per gallon of $Na_3PO_4 \cdot 12H_2O$. The test is sensitive to 0·01 mg. of phosphate. The test is also slightly sensitive to silicates, but as these are not likely to be present in a boiler blow-down water, this fact is not of significance.

TABLE I.   FOR USE WITH CLARK'S SOAP SOLUTION

c.c. soap solution	Parts CaCO₃ per 100,000	c.c. soap solution	Parts CaCO₃ per 100,000	c.c. soap solution	Parts CaCO₃ per 100,000	c.c. soap solution	Parts CaCO₃ per 100,000	c.c. soap solution	Parts CaCO₃ per 100,000	c.c. soap solution	Parts CaCO₃ per 100,000
0·7	0·00	3·3	3·64	5·9	7·29	8·5	11·05	11·1	15·00	13·7	19·13
·8	0·16	·4	3·77	6·0	7·43	·6	11·20	·2	15·16	·8	19·29
·9	0·32	·5	3·90	·1	7·57	·7	11·35	·3	15·32	·9	19·44
1·0	0·48	·6	4·03	·2	7·71	·8	11·50	·4	15·48	14·0	19·60
·1	0·63	·7	4·16	·3	7·86	·9	11·65	·5	15·63	·1	19·76
·2	0·79	·8	4·29	·4	8·00	9·0	11·80	·6	15·79	·2	19·92
·3	0·95	·9	4·43	·5	8·14	·1	11·95	·7	15·95	·3	20·08
·4	1·11	4·0	4·57	·6	8·29	·2	12·11	·8	16·11	·4	20·24
·5	1·27	·1	4·71	·7	8·43	·3	12·26	·9	16·27	·5	20·40
·6	1·43	·2	4·86	·8	8·57	·4	12·41	12·0	16·43	·6	20·56
·7	1·56	·3	5·00	·9	8·71	·5	12·56	·1	16·59	·7	20·71
·8	1·69	·4	5·14	7·0	8·86	·6	12·71	·2	16·75	·8	20·87
·9	1·82	·5	5·29	·1	9·00	·7	12·86	·3	16·90	·9	21·03
2·0	1·95	·6	5·43	·2	9·14	·8	13·01	·4	17·06	15·0	21·19
·1	2·08	·7	5·57	·3	9·29	·9	13·16	·5	17·22	·1	21·35
·2	2·21	·8	5·71	·4	9·43	10·0	13·31	·6	17·38	·2	21·51
·3	2·34	·9	5·86	·5	9·57	·1	13·46	·7	17·54	·3	21·68
·4	2·47	5·0	6·00	·6	9·71	·2	13·61	·8	17·70	·4	21·85
·5	2·60	·1	6·14	·7	9·86	·3	13·76	·9	17·86	·5	22·02
·6	2·73	·2	6·29	·8	10·00	·4	13·91	12·0	18·02	·6	22·18
·7	2·86	·3	6·43	·9	10·15	·5	14·06	·1	18·17	·7	22·35
·8	2·99	·4	6·57	8·0	10·30	·6	14·21	·2	18·33	·8	22·52
·9	3·12	·5	6·71	·1	10·45	·7	14·37	·3	18·49	·9	22·69
3·0	3·25	·6	6·86	·2	10·60	·8	14·52	·4	18·65	16·0	22·86
·1	3·38	·7	7·00	·3	10·75	·9	14·68	·5	18·81		
·2	3·51	·8	7·14	·4	10·90	11·0	14·84	·6	18·97		

TABLE II. C.CS. CLARK'S SOAP SOLUTION (GRAINS PER GALLON CALCIUM CARBONATE)

c.c.	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
0	—	—	—	—	—	—	—	0·00	0·11	0·22
1	0·33	0·44	0·55	0·67	0·78	0·89	1·00	1·09	1·18	1·27
2	1·36	1·45	1·54	1·64	1·73	1·83	1·93	2·01	2·09	2·18
3	2·28	2·37	2·46	2·55	2·64	2·73	2·82	2·91	3·00	3·10
4	3·20	3·30	3·40	3·50	3·60	3·70	3·80	3·90	4·00	4·10
5	4·20	4·30	4·40	4·50	4·60	4·70	4·80	4·90	5·00	5·10
6	5·20	5·30	5·40	5·50	5·60	5·70	5·80	5·90	6·00	6·10
7	6·20	6·30	6·40	6·50	6·60	6·70	6·80	6·90	7·00	7·11
8	7·21	7·32	7·42	7·53	7·63	7·74	7·84	7·94	8·05	8·16
9	8·26	8·37	8·48	8·58	8·69	8·79	8·90	9·00	9·11	9·21
10	9·32	9·42	9·53	9·63	9·74	9·84	9·95	10·06	10·16	10·28
11	10·39	10·50	10·61	10·72	10·83	10·94	11·05	11·17	11·28	11·39
12	11·50	11·61	11·72	11·83	11·94	12·05	12·17	12·28	12·39	12·50
13	12·61	12·72	12·83	12·94	13·06	13·17	13·28	13·39	13·50	13·61
14	13·72	13·83	13·94	14·06	14·17	14·28	14·39	14·50	14·61	14·72
15	14·83	14·95	15·06	15·18	15·29	15·41	15·53	15·65	15·76	15·88
16	16·00	—	—	—	—	—	—	—	—	—

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CHAPTER VIII

EXAMINATION OF CANNED FOODS

THE examination of the canned food in the laboratory should begin with a careful scrutiny of the external appearance of the container. The appearance of rust spots must be regarded as an unsatisfactory sign, since they imply weak areas in the tin which will ultimately lead to perforation. Both ends of the can should be well dished—that is to say, that there should be external evidence of at least a partial vacuum in the can. Tightly bulged ends invariably indicate internal pressure, due to gas production which, in nearly all cases except fruit, can be attributed to bacterial action. Slack ends, or ends so slightly bulged that the defect can be corrected by hand pressure, do not necessarily imply a faulty pack. Such cans are known in the trade as " springers," and the condition may be due to some lack of vacuum at the time of packing, or to the can being exposed to a rather high temperature, such as the direct rays of the sun in summer. In most cases, when cans showing this defect are cooled, it will be found that they resume a normal appearance, with both ends concave.

Leaks
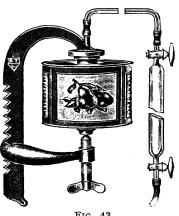
The can, before being opened, should be examined for leaks. This is important. Savage[1] considers leaks as a potent cause of unsoundness, " not because they admit bacteria, but because they allow the access of air. The admission of oxygen enables bacteria already present, but dormant, to resume their activities."

Large leaks are detectable by inspection, but it is difficult to find the smaller ones without submitting the can to test. Sometimes the leaks are closed by particles of the food, and may thus escape detection, but as a rule, if the can be placed in hot water and squeezed, air bubbles will be seen to arise from the hole in the can. One of the best methods for the detection of leaks is that practised in the National Canners' Laboratory in America, and described in detail by Savage. The method requires special apparatus not usually available in many laboratories. Provided that the can exhibits concave ends, is reasonably free from rust spots, and gives no indication of leaks, it can be passed as externally satisfactory.

Blown Cans

As regards the " blown " can, an examination of the gas content may be of some use, blowing being due not always to decomposition, but sometimes to hydrogen generated by the action of very acid fruit, such as apples, upon the metal container. The gas may be collected by means of the apparatus described in Allen's "Commercial Organic Analysis."[2 and 8] A hollow needle is fixed to the upper arm of a strong iron clamp ; the point and part of the lower part of the shaft of the needle are covered with a soft rubber cork, which acts as an air-tight pad. The can under examination is placed upon the lower arm of the clamp, which can be adjusted by means of a thumbscrew. The upper end of the needle is attached to a gas receiver by means of a capillary tube filled with mercury. When the screw on the lower arm of the clamp is turned so as to reduce the distance between it and the upper arm of the clamp, the hollow needle is forced into the can, and the liberated gas passes into the gas-receiving apparatus, stop cock eudiometer or nitrometer, where it may be subjected to the usual methods of analysis. Usually hydrogen, sulphuretted hydrogen and carbon dioxide constitute the chief constituents : but variation depends upon the nature

FIG. 43

APPARATUS FOR COLLECTION OF HEADSPACE GASES, FOR SUBSEQUENT ANALYSIS

Courtesy of Baird and Tatlock, Ltd.

of the organism causing spoilage, and the food in the can. It is not usually necessary to examine the gases contained in sound tins showing a good collapse.

Before cutting open the can for the purpose of examining the contents, it is most desirable to ascertain its freedom or otherwise from bacterial contamination.

It must be emphasised that the presence of living organisms in a can of food does not necessarily indicate that it is unsound, for the conditions under which the bacteria are placed may be such as to render their growth impossible, and consequently no spoilage can be brought about by their activity. Much depends upon the type of organisms found.

From time to time it will be found necessary to determine the amount of vacuum in filled and processed cans. This is carried out by means of a vacuum gauge fitted with a sharp, tapering, hollow needle, which just projects through a soft rubber bung. On pressing the bung tightly against the can, the needle pierces the tinplate, the rubber bung acting as a joint.

Metallic Contamination

The can may now be opened and its contents examined for the presence of tin, arsenic, lead, copper and zinc by the methods given later in this chapter and Chapter VI. Tin is almost invariably found, and may be present in amounts from a trace only, up to 2 to 3 grains per pound. Arsenic in small quantity is sometimes detected in canned crustacea, such as lobster, oysters, and shrimps, it being in many instances a common constituent of these fish. The presence of zinc is sometimes to be attributed to the use of zinc chloride as a soldering flux, and imperfect washing prior to filling.

The appearance of the inside of the can should be noted for discoloration; if excessive it indicates exposed iron due to faulty tinning of the plate or undue action of the contents upon the metal container. It is seldom necessary to condemn the article because of discoloration, which, while unsightly, is nearly always quite harmless.

It is sometimes desirable to make microscopic slides direct from the food in the can, for although no indication can thus be obtained whether the organisms found are alive or dead, it does show whether the food material was subjected to much bacterial contamination prior to its treatment in the can.

Canned Fruits

In canned fruits, the titratable acidity of the liquor may lead to useful information as to whether the article is likely to possess a highly corrosive action upon the container, if so it is probable that with age the metallic contamination of the food will increase and perforation ultimately take place.

The presence of preservative substances in canned foods is extremely rare, and is only likely to occur when the material has been treated before canning, or occasionally when the preservative substance is a natural constituent of the article. Boric acid has been found in tomatoes grown in Tuscany.

The Canned Food

The finished canned products that need routine analysis will include both those made upon the premises and those produced by competitors. The analysis of such samples will require at least one or possibly all of the following determinations to be made : percentage composition ; the quantity of tin, and possibly lead, copper, zinc and arsenic in the food ; acidity of the contents in the case of fruits, etc. ; artificial coal-tar colours ; in the case of " blown " cans, the nature of the gas generated by the organisms causing the decomposition ; the freedom or otherwise from bacteria. (The method of carrying out this test will be found under the section dealing with the microbiology of canned foods.)

Many government and other contractors specify that goods supplied shall comply with definite standards, and quite a number of countries also enforce standards of composition, particularly of meat products. When articles are manufactured in fulfilment of orders for either of these purposes, it is very necessary to ensure that they obey correctly the terms imposed.

Percentage Composition of Canned Meat, Meat and Fish Pastes, Sausages, etc.

On account of their nature, canned meat and fish products are by no means easy to can to a specified standard, even when all reasonable precautions are taken.

Quite a number of methods have been devised for the purpose of making the above determination, none are absolutely accurate, and some quite hopelessly inaccurate. The most reliable is that of Stubbs and More,[3] which has been subject to some modification by one of the authors.[4] It depends upon the fact that lean meats, that is defatted meats, possess a fairly uniform protein-water ratio, and also upon the assumption that the cereal matter, or " filler," usually carries approximately 40 per cent. of its weight of water.

It must be clearly understood that not only does the flesh of different animals of the same kind show a varying protein-water ratio, but also that different " cuts " of meat from the same animal are of varying composition, and therefore it has been necessary to base the average figures upon a very large number of samples. Further, in some of the low priced articles, some manufacturers use as a basis corned beef and canned boiled mutton ; in the final product these articles will have been twice canned. The protein-water ratio of meats treated in this manner shows such great variation that their presence in a sample along with fresh meat leads to great inaccuracy in calculations based upon the protein figure given by the mixture. No method has as yet been successfully devised by which this difficulty can be overcome, and where the presence of re-canned meat is suspected, the analyst has perforce to be content with the determination of the starch, salt and fat and to designate, as lean meat, the difference between the sum of these figures and 100. Where soya meal, or some other highly nitrogenous cereal substance, has been used the interpretation of the analytical data is an even more obscure problem.

The following determinations should be made of fresh foods : total water, ash, nitrogen, fat, salt, and microscopical examination with the object, if possible, of ascertaining the nature of the filler.

Water. About five grammes of the sample, accurately weighed, are intimately mixed with about 20 grammes of *freshly ignited* silver sand, the weight of which has been determined. It is advisable to weigh in

with the sand a short piece of glass rod, to be used in making the mixture. The whole is then dried at 100° C. in the air oven until the weight is constant. Loss in weight gives total moisture. The dried residue is retained for the determination of the fat.

Fat. The residue left, after the determination of the water, is carefully transferred to a Soxhlet extraction apparatus, and the fat extracted by the use of methyl ether of sp. gr. 0·720.

The weight of fat obtained is calculated as a percentage of the whole sample. The actual quantity extracted depends upon the weight of the material which was used in the determination of the moisture.

Nitrogen. This is determined by the Kjeldahl Gunning method, which is applicable to all kinds of foods. Weigh accurately about 2 grammes of the substance into a Kjeldahl flask. If the paste is of a sticky nature it will be found troublesome to transfer it from the receptacle in which it has been weighed into the flask. This difficulty can be overcome by weighing a short piece of glass tube, placing in it about 2 grammes of the sample under examination, and again weighing. The piece of tube containing the material is then transferred to the flask. Add about 25 c.cs. of concentrated sulphuric acid, 0·1 gramme of powdered selenium and 10 grammes of potassium sulphate. Heat with a small flame. Great caution is necessary to prevent foaming in the early stages of digestion. Continue heating until the solution has become quite clear, and almost colourless. Cool, then transfer the contents of the flask to a distillation flask, using 3 successive quantities of 80 c.cs. of water. Add a small piece of pumice, a few drops of methyl orange solution, and sufficient of a 30 per cent. solution of sodium hydroxide to render the contents highly alkaline. At once connect the flask to an upright condenser by means of a trapped still-head, and distil with the outlet end of the condenser dipping under a measured volume of deci-normal sulphuric acid, to which a few drops of methyl orange solution have been added. Continue the distillation until the whole of the ammonia has passed over into the acid. This point may be ascertained by allowing one or two drops of the distillate to fall upon a red litmus paper. The standard acid in the receiving flask is then titrated with tenth-normal sodium hydrate, and the difference in the number of c.cs. required (less that needed for a blank upon the materials used), and the number of c.cs. of standard acid used to receive the distillate, gives the number of c.cs. of deci-normal ammonia formed. This figure multiplied by 0·0014 and by 100 and divided by the weight of material taken, will give the percentage of nitrogen. For foods, other than milk, the nitrogen figure multiplied by 6·25 gives the percentage of protein. For milk and milk products, the protein factor is 6·38.

Ash. This is determined in the usual manner, working with 2 or 2·5 grammes, the ignition being made in a platinum crucible. As sodium chloride is volatile at high temperatures, the ash will not give the true

weight of mineral substances in the sample. For this reason the salt must be determined in a separate portion of the sample and also in the ash. The difference between the two figures will give the correct amount of sodium chloride present.

Salt. 20 grammes of the sample are extracted by boiling with water, and the aqueous portion filtered through a *wet* paper (in order to retain the fat in the paper). The extraction is repeated at least once, the two extracts mixed and made up to a volume of 250 c.cs. 50 c.cs. of the diluted extract is then titrated with standard silver nitrate solution, of tenth-normal strength (1 c.c. is equivalent to 0·00585 grammes of sodium chloride).

The calculation. [3 and 4] The percentage of non-fatty solids (100=water + fat) less the sum of the protein and the corrected ash (the ash, after the necessary adjustment for salt has been made) gives the amount of carbohydrate and crude cellulose material. If this be multiplied by 2, the approximate percentage of bread or cereal filler containing 40 per cent. of its weight of water is obtained.

One per cent. of the filler is regarded as nitrogen present in the filler, and if this quantity be deducted from the total nitrogen, the nitrogen due to the meat is found. To obtain the percentage of defatted meat the meat nitrogen is multiplied by 100, and divided by the percentage of nitrogen found to be the average for the kind of meat, or fish, which is present in the sample. In the case of pork this is 3·3, of beef 3·2, and of mixed pork and beef 3·25. The nitrogen content of some other meats and fish is : chicken, 3·65 per cent. ; rabbit, 3·43 per cent. ; and duck, 3·70 per cent. ; lobster, edible portion, 2·62 per cent. ; salmon, 2·85 per cent. ; and shrimp, 2·80 per cent.

The total percentage of meat or fish in the sample is the sum of the fat and the defatted flesh. 100 — the sum of the " filler " (containing 40 per cent. of its weight of water), the ash, and the total meat will give the amount of added water, that is to say, water other than that naturally present in the meat, and that present in the filler containing 40 per cent. of its weight of water.

A check on the analysis can be obtained as follows : the total percentage of moisture found by direct estimation should be equal to the sum of 40 per cent. of the filler, and the quantity naturally present in the meat (dependent upon the protein-water ratio of the meat, which can be calculated from the average nitrogen figure), and the added water, if any. The discrepancy should not exceed 2 per cent. unless a filler of high nitrogen content has been employed.

With the exception of the method for the determination of fat, the corrections for the total ash, and the nitrogen figures for various kinds of meat, the method described is that of Stubbs and More.[3]

Starch. 20 grammes of the sample (or less, if much starch is expected

to be present) are treated in a beaker with about 300 c.cs. of a 5 per cent. alcoholic solution of potassium hydroxide, the mixture being digested upon the water bath, until all but the starch and a little crude cellulose is dissolved. The solution is then filtered at the pump, the whole of the contents of the beaker being transferred to the filter paper. Washing is continued until the washings are no longer tinted yellow by the alcoholic potash. The starch is then washed off the filter paper into a beaker with warm water, the volume being made up to about 200 c.cs. Just sufficient dilute aqueous caustic potash is added (about 35 to 40 c.cs. of approximately normal strength) until the starch is dissolved. It may be necessary at this stage to warm gently the contents of the beaker, but boiling should be avoided. The solution is cooled, transferred to a 250 c.c. flask, made up to the mark, and 50 c.cs. are taken and added to 300 c.cs. of 90 per cent. alcohol, previously acidified with acetic acid. The whole is then stirred and the precipitated starch allowed to settle, preferably over-night. Filtration is effected upon a tared filter paper, and the precipitate washed with 90 per cent. alcohol until the washings are free from acid. The filter paper and its contents are dried in the oven, and weighed until constant. This is followed by ashing, the necessary correction being made for the weight of the ash.

Percentage Composition of Canned Fruits

In the majority, the determination of water, ash, sugar, nitrogen, ether extract and fibre, will provide the information required.

In fruits containing stones, these should be removed and weighed separately. The residual material, or in the case of stoneless fruits, the whole contents of the can, are mixed to a homogeneous pulp, from which the various portions for analysis are drawn.

Water. 5 grammes of the sample are dried to constant weight at a temperature not exceeding 70° C., in a vacuum drying oven, and the residue retained for ether extraction.

Ash. 2 grammes of the substance are first dried, and then ignited, in a platinum crucible at a dull red heat. Although some hours of heating may be found necessary to remove all the carbon, it is inadvisable to raise the temperature, as by so doing volatile salts may be lost.

Ether Extract. The residue remaining after the determination of the moisture is transferred to a continuous extractor of the Soxhlet type, dry alcohol-free ether (sp. gr. 0·720) being used as a solvent. Extraction is continued for a period of sixteen hours. The extract is dried to a constant weight in the water oven at 100° C.

Nitrogen (Protein). This is determined upon 2 grammes of the substance by the Kjeldahl method described under meat analysis.

Fibre. Transfer the residue from the ether extract to a 750 c.c. flask.

add 200 c.cs. of a 1·25 per cent. boiling solution of sulphuric acid (the strength of the acid must be exact), connect the flask with a reflux condenser, and raise the contents to boiling point as quickly as possible. Continue boiling gently for exactly 30 minutes, if necessary gently agitating the flask to wash down any material which has crept up the sides of the flask. At the end of the period, filter through a piece of linen, wash once with boiling water and return the residue on the linen to the flask, rinsing it into the flask with 200 c.cs. of boiling 1·25 per cent. sodium hydrate (of correct strength) which should be as free as possible from sodium carbonate. Raise to boiling point as rapidly as possible, and continue boiling for exactly 30 minutes. Filter on to a tared filter paper, wash with boiling water till free from alkali, dry at 105° C., and weigh. Then incinerate completely, deduct the weight of the ash from the weight of the fibre found, the difference being fibre.

A modification may be introduced by washing the alkaline extract in the above routine with dilute acetic acid, and then with boiling water until the washings are acid free. It will be found less troublesome to wash out the acid and sodium acetate than it is to remove the caustic soda from the fibre.

Sugar. From 100 deduct the sum of the water, ash, ether extract, protein and fibre. The remainder is sugar. For the more exact determination of the sugar the reader is referred to Leach[5] or other textbooks detailing the analysis of jams and sugar products. For practical purposes the method described above should give the necessary information.

Acidity. 50 grammes of the sample (or less if much acid is present) are extracted with three successive quantities of about 250 c.cs. of hot water. The extracts are filtered, and the residue on the filter paper washed into the same 1,000 c.c. graduated flask. The volume is made up to the mark, 100 c.cs. titrated with tenth-normal sodium hydrate, using phenol phthalein as an indicator (1 c.c. is equivalent to ·0075 grammes tartaric acid, ·0067 grammes malic acid and ·0064 grammes citric acid.) The acid will be expressed as one of these three according to the kind of fruit under examination, and the organic acid which is likely to predominate in it.

The percentage of water and protein in some of the more common vegetables and fruits is as follows.

Atwater and Bryant[6] and Ballard.[7]

Edible portions of—				Water.	Protein.
Asparagus	..	..	.	94·0	1·8
Beet	..	..	.	87·5	1·6
Cabbage	..	:.	.	91·5	1·6
Carrot	..	..	.	88·2	1·1
Celery	...	..	..	94·5	1·1
Mushrooms	..	..	.	88·1	3·5

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Edible portions of–	*Water.*	*Protein*
Tomato	94·3	0·9
Apples	84·6	0·4
Apricots	85·0	1·1
Blackberries	86·3	1·3
Cherries	80·9	1·0
Pears	84·4	0·6
Pineapple	89·3	0·4
Plums	78·4	1·0
Raspberries	85·8	1·0
Strawberries	90·4	1·0
Peas	12·4	20·6
Beans	15·2	18·2
Lentils	12·6	22·3
Potatoes	78·3	1·6

Milk

In examining canned milk, the quality to some extent may with experience be judged by eye, in fact, some of the tests commonly applied are entirely of this nature, such as appearance, smoothness and colour. In addition to these it is usual to carry out tests for the viscosity, although this is not the general rule, fat content, total solids, and, although it is not always employed, the determination of sucrose.

Viscosity. For ordinary commercial practice the Mojonnier-Doolittle[8] viscometer is used generally. The readings obtained are relative only. Under standardised conditions they are, of course, strictly comparable. The standard viscometer is fitted with viscosity balls giving three ranges of viscosity. The largest is applicable to less viscous fluids, such as fresh whole milk ; the medium viscosity ball is applicable to evaporated milk, cream and similar products, whilst the smallest is used for sweetened condensed milk. The viscometer is of the tortional type, the ball is lowered into the milk sample and turned by rotating the calibrated disc to which it is attached, clockwise through one revolution. The trip is released, and the dial marking to which the dial revolves before swinging back again is noted. This represents the viscosity of the sample and is expressed as degrees of retardation. The tests must be carried out at constant temperature. For more accurate work of the research type Loveless[9] has designed a modification eliminating what may be called the " flip " effect inseparable from the cruder type of mechanism.

Total Solids

There are several methods of determining these, and below is that recommended by the Subcommittee of the Standi g Committee on the Uniformity of Analytical Methods[10] of the Society of Public Analysts. This is taken from the *Analyst.*

Sand. Sand is used which passes a 30 mesh and is retained by a 90 inch mesh sieve. Heat a convenient quantity of this sand with strong hydrochloric acid to remove oxide of iron, etc. ; decant ; repeat the digestion till the acid liquor is nearly colourless ; wash, once with dilute hydrochloric acid, and then thoroughly with distilled water ; dry and ignite.

The sand thus prepared should be tested for suitability as follows ; dry a portion at 98° to 100° C., and weigh; moisten with distilled water and subsequently dry again at 98° to 100° C. There should be no difference between the two weights.

Dishes. These should be of metal (aluminium or nickel is suitable) with readily removable but close fitting lids ; a suitable size is of diameter about 3 inches and depth about 1 inch.

Procedure for Sweetened Condensed Milk. Place about 25 grammes of the prepared sand and a short glass stirring rod in the dish and dry to constant weight in an oven at 98° to 100° C., the lid being removed whilst drying and replaced before removing the dish from the oven. Allow the dish to remain 45 minutes in the desiccator before weighing.

Tilt the sand to one side of the dish ; place on the clear space about 1·5 grammes of the sample and weigh rapidly. Add 5 c.cs. of water to the milk, and mix these ; then mix the diluted milk thoroughly with the sand by means of the rod.

Place the dish on a rapidly boiling water bath for 20 minutes, carefully stirring during the earlier period. Transfer the dish, with rod and cover, to a well ventilated oven at 98° to 100° C., as recorded by a thermometer in the air immediately above the dish. After 1½ hours cover the dish and place in a desiccator for 45 minutes, weigh ; return the dish to the oven, and heat for one hour with lid removed ; remove and weigh as before ; repeat this process until the loss in weight between successive weighings does not exceed 0·0005 gramme.

For Unsweetened Condensed Milk. Weigh out 3 grammes of condensed milk and use 3 c.cs. of water, otherwise proceed as above.

Mojonnier's Method. This[8] is slightly different in detail although the principle is similar. It is generally regarded as the most practical for works use, and should be carried out as follows for evaporated and unsweetened condensed milks. A 1 gramme sample is taken in the sample dish, to this is added 1 c.c. of water, the two are mixed and spread in a thin film over the entire bottom of the sample dish. The dish is then placed in direct contact upon a hot plate at a temperature of 180° C., and heated until the first traces of brown begin to appear in the residue. The dish is then transferred to a vacuum oven maintained at 100° C. The dish should be kept in the oven for 10 minutes under vacuum of not less than 20 ins. It is then transferred to a cooling desiccator and held

there for five minutes with the water circulating pump operating continuously.   The dish is then removed and rapidly weighed.

For sweetened condensed milk a 0·25 gramme sample is used and measured by pipette.   The 4 or 5 small drops necessary should be placed in different parts of the dish so that the milk may be more readily dissolved by the 2 c.cs. of hot water, which is then added.   Since sweetened condensed milk is apparently slow in dissolving it is important to make a good mixture and to spread it in a thin film over the entire bottom of the dish.   The same process as already outlined is carried out, except that the dish should be kept in the vacuum oven for 20 minutes.   Complete drying is not effected and it is necessary to deduct 0·30 per cent. from the total solids obtained.

Fat in Sweetened and Unsweetened Condensed Milk

Probably the most widely practised method for this determination in Great Britain, is the Gerber method, as already described in Chapter V.   The following is that approved by the Subcommittee of the Committee on Analytical Methods already referred to.

Reagents.   Concentrated ammonia solution, nominal 0·880 ;   alcohol or industrial methylated spirit, 95 per cent. by volume.

Petroleum spirit boiling between 40° C. and 60° C.   These reagents should leave no appreciable residue on evaporation.

Procedure.   Transfer to a suitable apparatus from 2 to 2·5 grammes, accurately weighed, of the well mixed sample ;   add 8 c.cs. warm water and mix well ;   cool, add 1 c.c. of concentrated ammonia solution, mix ;   add 10 c.cs. of alcohol and again mix.   Add 25 c.cs. of ether and shake vigorously for one minute ;   add 25 c.cs. of petroleum spirit and again shake vigorously for 30 seconds.   Allow the liquids to stand for not less than half an hour, until the ethereal layer is perfectly clear, or centrifuge at low speed.   Transfer the ethereal layer to a suitable flask.   To the milk residue add 5 c.cs. of ether, and transfer without further shaking ;   repeat this operation in the same manner with a further 5 c.cs. of ether.   Add 0·5 c.c. alcohol, and repeat the extraction with 25 c.cs. of ether, and 25 c.cs. of petroleum spirit, as before, shaking vigorously for one minute after the addition of the ether, and 30 seconds after the addition of the petroleum spirit.   As before allow the ethereal layer to separate completely and transfer to the flask.   Repeat the extraction once more with alcohol, ether and petroleum spirit in the same manner.

Cautiously distil the solvents from the flask and dry the residual fat at 98° to 100° C. to constant weight, taking the ordinary precautions to remove all traces of the volatile solvent.

Completely extract the fat from the flask by repeated washings with petroleum spirit, allowing any sediment to settle before each decantation. Finally dry the flask at 98° to 100° C.   The difference in weights before and

after the petroleum spirit extractions is the weight of fat contained in the quantity of condensed milk taken.

Make a blank determination, using the specified quantities of reagents, and distilled water in place of the milk, and deduct the figure found, if any, from the weight of fat obtained.

Determination of Sucrose in Sweetened Condensed Milk

There are several ways of carrying this out ; the following is that of the Subcommittee already referred to.[11]

Reagents. Zinc acetate solution : 21·9 grammes of crystallised zinc acetate, $Zn(C_2H_3O_2)_2 \cdot 2H_2O$ and 3 c.cs. of glacial acetic acid in water, made up to 100 c.cs.

Potassium ferrocyanide solution : 10·6 grammes of crystallised potassium ferrocyanide in water made up to 100 c.cs.

Hydrochloric acid solution : 6·34 times normal.

Concentrated ammonia solution : nominal 0·880.

Dilute ammonia solution : 10 c.cs. concentrated ammonia solution diluted with water to 100 c.cs.

Dilute acetic acid solution : approximately equivalent to the dilute ammonia solution.

Apparatus. The instrument used for measuring the optical rotation may be either a polarimeter or a saccharimeter ; using, for the polarimeter, sodium light, or the green line of the mercury spectrum separated by means of a prism or by the use of a special Wratten screen No. 77a ; and for the saccharimeter white light from an incandescent electric lamp after passing through 15 mm. of a 6 per cent. solution of potassium bichromate.

Tubes, of not less than 2 dm., exactly calibrated for length.

Flasks and pipettes accurately calibrated.

A standard thermometer, reading to 0·1° C.

Preparation of the sample. Mix the sample in the manner previously described.

Procedure. Zinc Serum : transfer to a 100 c.c. beaker an accurately weighed quantity, approximately 40 grammes, of the well-mixed sample ; add 50 c.cs. of hot distilled water (80° to 90° C.) mix, transfer to a 200 c.c. measuring flask, washing in with successive quantities of distilled water at 60° C., until the total volume is from 120 to 150 c.cs. Mix, cool to air temperature, and then add 5 c.cs. of the dilute ammonia solution. Again mix, and allow to stand for 15 minutes. Add a sufficient quantity of the dilute acetic acid solution to neutralise the ammonia added (the exact equivalent is determined beforehand by titration) and again mix. Add with gentle mixing 12·5 c.cs. of zinc acetate solution and mix, followed in the same manner by 12·5 c.cs. of potassium ferrocyanide solution.

Bring the contents of the flask to 20° C. and add distilled water at 20° C. up to the 200 c.c. mark.

Up to this stage all additions of water or reagents should be made in such a manner as to avoid formation of air bubbles, and, with the same object in view, all mixings should be made by rotation of the flask rather than by shaking. If bubbles are found to be present before completion of dilution to 200 c.cs., their removal can be assisted by temporary attachment of the flask to a vacuum pump, and rotation of the flask.

Close the flask with a dry stopper and mix thoroughly by shaking. Allow to stand for a few minutes and then filter through a dry filter paper, rejecting the first 25 c.cs. of the filtrate.

Direct Polarisation. Determine the rotation of the filtrate at 20° C.

Inversion. Pipette 40 c.cs. of the filtrate obtained as above into a 50 c.c. flask, add 6 c.cs. of 6·34 normal hydrochloric acid. Immerse for 12 minutes the entire bulb of the flask in a water bath maintained at 60° C., mixing by rotatory movement during the first three minutes, in which time the contents of the flask should have attained the temperature of the bath. Cool, dilute to 50 c.cs. at 20° C. with distilled water, mix and allow to stand for one hour.

Invert Polarisation. Determine the rotation at 20° C.

Calculation.

W = weight of sample taken in grammes.
F = percentage of fat in the sample.
P = percentage of protein (N × 6·38) in the sample.
V = volume to which the sample is diluted before filtration.
v = correction in c.cs. for volume of precipitate produced during clarification.
D = observed direct polarimeter reading.
I = observed invert polarimeter reading.
l = length of tube.
Q = inversion division factor.

Then $v = \dfrac{W}{100} [(F \times 1·08) + (P \times 1·55)]$

and the percentage of sucrose in the sample

$$\frac{D - (\tfrac{5}{4} \times I)}{Q} \times \frac{V - v}{V} \times \frac{V}{1 \times W}$$

The Inversion Divisor Factor (Q).* The rotation of sugars is affected by salts and acids, and also by the influence of the concentration of the sugars in solution.

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* " Q " is the change in specific rotation of sucrose on inversion, divided by 100.

The divisor factors obtained under the conditions of the process described are as follows :

	Zinc acetate potassium ferrocyanide precipitant.	Phosphotungstic acid precipitant.
Sodium light	(i) 0·8825	(iv) 0·8865
Mercury green line (prism of special Wratten screen 77a)	(ii) 1·0392	(v) 1·0439
International sugar scale (j) light .. .	(iii) 2·549	(vi) 2·561

The Analysis of Sweetened Condensed Milk in which the Sucrose has altered during Storage.[12] (1) Sweetened condensed milk should be examined by the modified Barfoed process described below.

(2) If no significant alteration is disclosed by this examination, the percentage of total milk solids should be determined by subtracting the percentage of sucrose determined by the method given above from the percentage of total solids.

(3) If significant alteration is disclosed, the percentage of total milk solids should be determined by subtracting the percentage of original sucrose, determined as described later, from the percentage of total solids.

Modified Barfoed Process

Reagent. Copper solution : dissolve 60 grammes of crystallised sodium acetate in water, add 105 c.cs. of normal acetic acid and make up to 1 litre with water. Transfer to a dry bottle, add 52 grammes (or more) of finely powdered crystallised copper acetate and shake to saturation. Filter.

Ferric sulphate solution : Dissolve 50 grammes of ferric sulphate in 400 c.cs. of water, to which 109 c.cs. of concentrated sulphuric acid has been added. Make up to 1 litre and filter. Before use, this solution should be treated with deci-normal permanganate solution until the colour of the latter ceases to be discharged.

Procedure. Introduce 25 c.cs. of the zinc serum (prepared as described under the determination of sucrose in sweetened condensed milk, see page 141) into a thin-walled boiling tube (internal measurements 8 × 1¼ inches) ; add 70 c.cs. of the copper solution ; mix ; cover the tube with a watch-glass and immerse (to the level of the liquid in the tube) in the water in a large water bath maintained at 80° C. for 20 minutes. Remove ; cool in running water ; filter on asbestos* by suction and wash the tube

* A convenient asbestos filter may be prepared by inserting a loosely fitting glass bead into the neck of an Allihn filter tube ; above the bead is placed a layer of glass wool, and on this is laid the asbestos, which is added as a wet pulp and drawn on to the glass wool by suction. Solution of the cuprous oxide is rapidly effected by pipetting the ferric sulphate solution into the reduction tube, transferring to the Allihn tube, and thoroughly mixing the surface asbestos layers with the sulphate solution by means of a flat-ended glass rod, leaving the lower asbestos layers and the glass wool undisturbed.

and filter containing the cuprous oxide rapidly a few times with freshly boiled distilled water, rejecting the filtrate and washings. Dissolve the cuprous oxide (including any remaining in the tube) in 20 c.cs. of the ferric sulphate solution ; wash the asbestos pad with cold freshly boiled distilled water, adding the washings to the ferric sulphate filtrate, and titrate with deci-normal permanganate to a faint permanent pink.

If the titration exceeds about 15 c.cs. of N/10 permanganate the test should be repeated with a suitable quantity of the serum made up to 25 c.cs. For specially accurate work this dilution should be made with a serum prepared from fresh milk and sucrose.

Determination of the " Original Sucrose." This is carried out as previously described (see page 141) followed by the chloramine-T titration.

Reagents. Phosphotungstic acid serum.

Reagent. Phosphotungstic acid precipitant : 50 grammes of crystalline sodium tungstate $Na_2WO_4 \cdot 2H_2O$ and 6 grammes of crystalline disodium phosphate are dissolved in about 200 c.cs. of distilled water, and 220 c.cs. of twice normal hydrochloric acid solution (or the equivalent amount of acid of other normality) are added slowly with stirring. The solution is diluted to 500 c.cs. and filtered. The acidity of the reagent should be so adjusted that 20 c.cs. require approximately 16 c.cs. of N/2 sodium hydroxide solution when titrated with methyl orange as indicator, and the p_H of the reagent, diluted to five times its volume with water, is approximately 1·3.

Procedure. Transfer to a 200 c.c. measuring flask an accurately weighed quantity of the well mixed sample, by successive quantities of distilled water at about 60° C., using about 120 c.cs. of water in all. Mix ; cool to air temperature, and add with gentle mixing 10 c.cs. of the phosphotungstic acid reagent. Bring the contents of the flask to 20° C. and add distilled water (at 20° C.) up to the 200 c.c. mark.

Up to this stage all additions of water or reagents should be made in such a manner as to avoid formation of air bubbles.

Close the flask with a dry stopper and mix thoroughly by shaking. Allow to stand for ten minutes, and then filter through a dry filter paper, rejecting the first 25 c.cs. of the filtrate.

(In small samples the full quantity given above may not be available. If the prescribed quantity of 10 grammes is departed from, the amount of phosphotungstic acid reagent must be varied so that its volume in c.cs. is numerically equal to the weight of the sample taken in grammes. The calculation which follows for the phosphotungstic acid serum holds only when this relationship is maintained and for a 5 per cent. serum.)

Chloramine-T Titration. N/20 chloramine-T solution : containing 7·04 grammes per litre, freshly prepared and protected from light.

Standard sodium thiosulphate solution : preferably rather stronger than $N/20$ so that 50 c.cs. of the chloramine-T solution can be titrated without refilling a 50 c.c. burette.

The thiosulphate solution must be accurately standardised against pure potassium bichromate by the method of Popoff and Whitman.

$N/2$ sodium hydroxide solution.

$N/10$ sodium hydroxide solution.

Soluble starch : Approximately 2 per cent.

Procedure. Inversion. Pipette 25 c.cs. of the phosphotungstic acid serum into a 100 c.c. measuring flask, add 15 c.cs. distilled water and 5 c.cs. of $6 \cdot 34N$ hydrochloric acid. Immerse for 12 minutes the entire bulb of the flask in a water bath maintained at 60° C., mixing by rotatory movement during the first three minutes, in which time the contents of the flask should have attained the temperature of the bath. Cool, add $N/2$ sodium hydroxide solution, continually mixing, until neutral, carrying the addition of the alkali to the point of definite turbidity (no internal indicator should be used). Cool, make up to the 100 c.c. mark at 20° C. with distilled water.

Titration of inverted and neutralised serum. Into one of two 250 c.c. flasks or bottles pipette 25 c.cs. of the inverted neutralised serum, which has been diluted to 100 c.cs. ; into the other, pipette 25 c.cs. of water (as a blank). To each add 3 c.cs. of $N/10$ caustic soda solution, followed by 20 c.cs. of 10 per cent. potassium iodide solution, then into each, pipette accurately 50 c.cs. of the $N/20$ chloramine-T solution ; close the flasks or bottles and leave in the dark for $1\frac{1}{2}$ hours at a temperature of from 17° to 18° C. At the end of this time add to each flask 10 c.cs. of 2N hydrochloric acid, and titrate at once with the thiosulphate solution, with starch solution as an indicator.

All measuring flasks, pipettes and burettes must be accurately cali-brated, special attention being paid to drainage of the burette, which should be calibrated in the manner in which it is used for the titration. Readings of the burette are made to 0·01 c.c.

Calculation.

S   = percentage of " original sucrose " in the sample.

E   = iodine absorbed by 100 grammes of the sample.

W   = weight of sample taken in grammes.

F   = percentage of fat in the sample.

P   = percentage of protein $(N \times 6 \cdot 38)$ in the sample.

V   = volume in c.cs. to which the sample is diluted before titration.

v   = correction in c.cs. for volume of precipitate produced during clarification.

n   = difference between inverted serum and the blank titrations in the $N/20$ thiosulphate solution.

Then for the calculation of the original sucrose :

$$V = \frac{W}{100} \left[(F \times 1 \cdot 08) + (P \times 0 \cdot 74) + 3 \cdot 75 \right] \text{ c.c.}$$

$$E = (n - 0 \cdot 15) \times 63 \cdot 46 \times 0 \cdot 032 \times \frac{V - v}{V}$$

$$S = 0 \cdot 964 \, E \, - 1 \cdot 29 \, R$$

For the full report of the Subcommittee the reader is referred to the bibliographical references to the *Analyst*.

Ash. Weigh 5 grammes of the sample in a tared platinum dish, evaporate to dryness on the water bath, and then ignite to dull redness in a muffle furnace until a perfectly white ash is obtained. Weigh, and multiply the residue found by 20, which gives the percentage of ash.

Protein. Weigh 5 grammes of the sample into a Kjeldahl flask, evaporate away the water by gentle heat, cool, and then proceed in the usual manner for the determination of nitrogen by the Kjeldahl Gunning method.

Tin

Fifty grammes of the sample are placed in a Kjeldahl flask along with 50 c.cs. of concentrated sulphuric acid and heated over a small flame, during which period nitric acid (concentrated) is added drop by drop, until all the organic matter has been oxidised. Care must be exercised to prevent undue foaming. When the liquid has become clear, after further heating until all the nitric acid is removed, the solution is allowed to cool, water added, and the contents of the flask transferred to a large beaker. The mixture is then boiled, diluted to at least three times its volume, filtered and sulphuretted hydrogen passed until saturation with this gas is reached. After standing for some hours, the precipitate, which may also contain copper and lead, is filtered, washed with sulphuretted hydrogen solution, and the precipitate dissolved in dilute sodium hydroxide. The residue on the filter paper will consist of the sulphides of lead and copper, if either or both of these metals are present. The filtrate which contains the tin is diluted if necessary, acidified with acetic acid and again saturated with sulphuretted hydrogen. The precipitate is filtered off, dissolved in concentrated hydrochloric acid, reduced with zinc, and then titrated with N/50 iodine solution. Alternatively the tin may be determined colorimetrically by Buchanan and Schryer's method[13] which is as follows : The solution of the tin in concentrated hydrochloric acid, prepared as above, is reduced with zinc, and a continuous current of carbon dioxide gas is passed through the liquid. When the whole of the zinc has dissolved, 2 c.cs. of a reagent prepared by dissolving 0·2 gramme of dinitro-diphenylamine-sulphoxide in 100 c.cs. of tenth-normal sodium

hydroxide, is added. The solution is heated for two minutes, during which period the current of carbon dioxide gas is maintained. Dilute with an equal volume of water, add three drops of ferric chloride solution, and filter. The presence of tin will cause the filtrate to assume a violet colour, the intensity of which will depend upon the quantity of that metal present. The colour produced is matched against various quantities of a solution containing a known quantity of tin, and which has been treated in precisely the same manner as that described. The standard solution should contain 0·2856 grammes of tin per 100 c.cs. 5 c.cs. of this solution are mixed with 5 c.cs. of water, and 1 c.c. of this dilution is equivalent to 1 grain per lb. of tin for every 10 grammes of the sample taken. The solution may be made from stannous chloride.

Lead

Fifty grammes of the sample are treated with sulphuric acid in the manner described under the determination of tin. Add excess of ammonia to the digest and then 2 to 3 grammes of solid ammonium acetate. The tin, iron and zinc (if any be present) will remain undissolved, the copper and lead pass into solution. Filter, wash, add 5 c.cs. of a 5 per cent. solution of potassium cyanide, and pass sulphuretted hydrogen. The volume of the liquid at this stage should not exceed 50 c.cs. Transfer to a Nessler tube, and compare the depth of the brown colour with various quantities of a standard solution of lead acetate, which has been treated with sulphuretted hydrogen water.

A suitable standard is made by dissolving 0·1831 grammes lead acetate in water and diluting the volume to 1 litre.

Copper

Fifty to one hundred grammes of the sample are evaporated to dryness and the residue treated with 10 to 15 c.cs. of concentrated sulphuric acid. The basin is then gently heated on a sand bath until foaming ceases and the contents assume a very pasty state. The dish is then transferred to a muffle, and ignited until all the carbon has been removed. It may be necessary to treat the material with a few drops of concentrated nitric acid to assist oxidation. The ash is taken up in dilute nitric acid, filtered, and excess of ammonia added to the filtrate and again filtered. In the presence of copper, a blue colour will be produced, the depth of which may be compared with that produced with known quantities of a standard solution of copper.

Standard copper solution is made by dissolving 0·3928 grammes of pure copper sulphate in 1 litre of water.

Zinc

The filtrate from the mixed sulphides of tin, copper and lead (produced by the first application of sulphuretted hydrogen, see under the determination of tin) if it exceeds 100 c.cs. in volume is concentrated to that amount, and then oxidised with bromine water to remove any excess of sulphuretted hydrogen and to convert the iron present to the ferric state. The bromine is boiled off, sufficient ferric chloride is added to make the solution a pale yellow, if not already so, ammonia is then added to almost neutralisation point, and the iron precipitated by the addition of a little solid ammonium acetate. Filter to remove the iron precipitate, and then carry out the test for zinc in the filtrate in accordance with the details given on page 92 in the detection of zinc in tin containers.

Arsenic

It may be necessary to determine if any arsenic is present, and if so to what amount. A Joint Committee of the Society of Public Analysts and the Society of Chemical Industry[14] published two methods in which the material is either treated by heating with acid, or by ignition with magnesia or lime, and the quantity of arsenic present determined by the Gutzeit method.

Treatment with Acid. 10 grammes of the material are heated upon a sand bath with 20 c.cs. of arsenic-free concentrated nitric acid, until nitrous fumes cease to be evolved, and then 1 c.c. of concentrated sulphuric acid is added, drop by drop, and heat again applied until only a charred mass remains. This is extracted with hot dilute hydrochloric acid (arsenic-free) and the extract filtered. The solution should be practically colourless.

Treatment with Magnesia or Lime. 10 grammes of the material are intimately mixed with an equal weight of pure lime or pure magnesia, if necessary the mixture dried on a gently heated hot-plate or sand bath, and then ignited in the muffle furnace at dull red heat. The residue is dissolved in dilute hydrochloric acid, and filtered.

Gutzeit Method. This method has been subject to many modifications since first published, and that which is given below is the standard adopted in the British Pharmacopœia.

A wide-mouthed bottle of 120 c.c. capacity is fitted with an indiarubber cork through which passes a glass tube, 200 mm. in length, of external diameter 7 mm. and 5 mm. internal diameter. The lower end of the tube is drawn out to 1 mm. diameter and a hole about 2 mm. is blown in the side of the tube just at the top of the constriction. A piece of filter paper, 100 × 40 mm., is soaked in lead acetate solution, and dried, then rolled round inside the tube to absorb any hydrogen sulphide generated. Over the top of the tube is secured by a rubber ring a piece

of mercuric chloride paper 5·5 cm. in diameter, prepared by soaking a smooth fine-texture filter-paper in saturated mercuric chloride solution and drying it in the oven. The mercuric chloride test papers should be recently prepared and stored in an air-tight tin in the dark. For the test, about 10 grammes of arsenic-free zinc are put in the bottle together with the solution to be tested, and 10 c.cs. of stannated hydrochloric acid. The cork carrying the tube and test paper is at once inserted, and the whole is stood in a warm place for at least 40 minutes. The intensity of the stain produced is matched against those produced in similar circumstances from known quantities of arsenious oxide. The stains for comparative purposes may be made to represent say 0·003, 0·004, 0·006 milligrams of As_2O_3. According to Cox,[15] the limit of sensi iveness of the test is about 0 003 mgs. of As_2O_3.

The test is sufficiently accurate for practical purposes in the food canning laboratory, and possesses the advantage over the Marsh-Berzelius test in that it can be much more rapidly carried out. If extreme accuracy is needed the reader is referred to the standard Marsh-Berzelius Test as recommended by the Joint Committee of the Society of Public Analysts and the Society of Chemical Industry.[14]

Artificial Colouring

According to Cox,[15] the addition of artificial dyes to fruit and vegetable products may be detected as follows :

Add a tuft of white wool to about 20 grammes of the sample diluted with 50 c.cs. of water, acidify with acetic acid, boil for five minutes ; remove the wool, wash it under the tap, then boil it with water containing a trace of alkali, which extracts the colour, remove the wool, acidify the solution, and boil it with a fresh piece of wool, wash the wool and dry in filter paper. The colour may then be identified by the ordinary tests.[16]

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CHAPTER IX

GENERAL OUTLINE OF THE MICROBIOLOGY OF CANNING

WITH the growth of the preservation of foods by hermetically sealing them in tin and glass, there has arisen the necessity for specialised bacteriological knowledge, and the employment of a technique differing widely from that acquired by students intended for the medical profession, whose chief concern lies with those organisms which exhibit pathogenic properties towards the human system. The food manufacturer, although not able entirely to disregard this class of bacteria, is in the main concerned with the habitat and behaviour of the very large class of organisms liable to cause spoilage of his products. They may be roughly classified as putrefactive organisms. His object is to control manufacturing operations in such a manner that his goods will never depreciate and become unfit for human consumption, and yet to turn them out in a palatable and attractive condition. This is by no means the simple procedure it may appear to the uninitiated.

Even in the factory, where all the steps in production have been laid down with the object of avoiding troubles caused by bacterial spoilage, occasions do arise when the manufacturer is faced with quite a number of batches of his goods which are unfit to place upon the market. It falls to the lot of the bacteriologist to ascertain the cause of the trouble, and to provide against a recurrence.

An admirable treatise on the subject was published in 1905, by the late Professor Duckwell,[1] and although bacteriological knowledge has made considerable advance since that date, many of the methods he employed are fully applicable to-day.

General Principles

The organisms responsible for spoilage are always present in abundance in places where food is handled and kept, and the problem resolves itself into how their activities can be so controlled that the minimum of trouble arises from their presence. There are general principles which can be adopted for the examination of canned foods.

It is obvious that if spoilage is to be prevented, the canned article must be subjected to treatment by which bacteria are either destroyed or rendered inoperative. Where possible, the former of these alternatives is much to be preferred, and the producer should aim for destruction of

bacteria.   All known organisms succumb to treatment by heat, but their resistance varies, and those which form spores are always more difficult to destroy.   The canner must therefore heat or cook his products to a sufficiently high temperature for the necessary length of time to kill all the organisms and their spores present in the food inside the container. In order to arrive at the correct process to which the material is to be subjected, two points have to be taken into consideration.   What are the most heat resistant organisms with which the food is likely to be contaminated, and how long will it take the heat to penetrate to the centre of the can or glass ?   In itself, heat penetration is a subject of some complexity, but its exact determination for every variety of food canned is absolutely essential unless failure is to be courted.   The length of time needed for the heat to reach the centre of the contents of the can, and to be maintained at that point for a sufficient period to destroy any spores present, having been found, then whatever the total time may be, it is the very minimum which can be used safely for the processing of that particular article.   There is a possible exception to this—when the article of food is of an acid nature, such as fruit or tomatoes, the processing time can be much reduced without running any undue risk, for the low p_H of the contents will inhibit bacterial growth.

It has been definitely established that the greater the amount of bacterial contamination the more difficult it is to destroy the organisms present.   Care must therefore be exercised to keep the raw material in the cleanest possible state, and to handle it as rapidly as possible after it arrives on the premises.   This applies to meat, fruit and vegetables, and to any material which contains more than a minimum of moisture. It is probable that meat, milk and fish are the most difficult articles to handle, for they are particularly prone to rapid decomposition.   Absolute cleanliness is an essential, and this can only be maintained by constant supervision and sterilisation of utensils and plant.

Classification of Bacteria

Bacteria belong to the lower vegetable kingdom, and are not properly called " germs " or " microbes," which terms embrace a larger meaning and include animalculæ and lower insect life.   The first known instance of the occurrence of bacteria was recorded by Leeuwenhock in 1683 ; he found them in scrapings from teeth.   In 1875, Cohn, Naegeli and others workers concluded that they belonged to the vegetable kingdom on account principally of their resemblance to the algae in their method of reproduction, growth and multiplication.   Until quite recently it was thought that bacteria were the smallest form of life, but the researches of Koch and others have led to the discovery of filterable viruses, now regarded as the cause of foot and mouth disease and other maladies.

The bacteria possess so few morphological attributes, and so many forms are pleomorphic, that it is almost impossible to formulate a scientific or convenient classification. There are, however, three very broad divisions — the Cocci, which grow as round or oval cells ; the Bacilli, which are rod-shaped in form ; and the Spirilla, which are of spiral formation. Further and more extended classifications are given in many textbooks, but these are likely to lead to confusion rather than to be of assistance to the canner.

There are many different kinds of bacteria which resemble one another in all that a microscope can reveal, and their identification depends upon their behaviour under varying conditions.

One fact has been definitely established ; one kind of bacillus never developes into another kind, but many species are known to change very completely in one or more respects. Duckwell quotes as an example *Proteous Zenkeri*, which on occasion suddenly divides into two classes, one of which will not liquefy gelatine, while the other persists in doing so. It is now generally recognised that, by continual culturing under special conditions, organisms can be made to change their behaviour to an extent that makes it difficult to identify them with the more generally accepted properties associated with their normal forms. Anærobes can be coaxed to grow under ærobic conditions ; ordinary *putrificus* can be converted into a thermophilic organism, and so on.

Propagation of Bacteria

Bacteria are asexual, and propagate by fission. When a cell has attained the maximum size for its species, it elongates with a constriction round the middle followed by a simple partition.

Bacteria are almost universally distributed, but they are not always in the full vegetating form. They become dried up, or, in the form of spores, are air- or water-borne until they lodge upon organic matter which furnishes them with the necessary material for growth. This is a multiplication which continues until certain conditions arise, such as change of temperature or chemical decomposition due to their own action, or to the products of other bacteria vegetating at the same time with them ; or conditions arising from natural causes, when they either die or pass into a dormant state. The resting stage is characterised by either a drying up of the cell membrane or the formation of spores. While it seems probable that nearly all bacteria give rise to spores of some kind, this has not been demonstrated as a fact because methods are not yet available for studying them under natural conditions ; in the laboratory they have to be artificially cultivated. It should be understood that spore formation cannot always be assigned to the causes stated above, because it is known to occur frequently when the conditions are at an optimum for rapid multiplication.

Spore Formation

The course of spore formation may be thus observed : The whole bacillus is first seen under the microscope as a colourless homogeneous cell, showing no bright spots. When it advances to the stage of spore formation, fine granules can be detected scattered throughout the cell, some very small, others larger and irregular. One bright spot continues to grow larger and brighter, and the other granules may be absorbed by it. The bright spot, at first irregular, now begins to assume definite shape, usually round, with a dark line forming around it which seems to grow thicker, forming a wall which appears to enclose all the contents or protoplasm of the cell—or, what is more probable, the protoplasm goes to form the spore wall. The old cell is now merely a shell containing the spore, which may soften and disappear in the surrounding fluid, leaving the spore in a free state. Spores develop in a certain position in organisms of the same kind, and may be terminal, median or intermediate. During spore formation the mother cell usually exhibits swelling, so that a bacillus with a terminal spore appears club-shaped in form, one with a median spore resembles a lemon, and the organism producing an intermediate form of spore is known as a " clostridium."

A clear distinction must be made between spore formation and vegetation ; spores correspond to the seed in higher plant life, and are formed for the perpetuation of the species, while the vegetation is a multiplication, not by seed formation but by fission, and may go on indefinitely if conditions of growth are favourable. In order that the spore may live through relatively great changes of temperature, etc., the spore walls are thick and not easily penetrated by heat or aniline dyes, so that with ordinary staining they do not " take " the stain to the same degree as do the vegetative forms of the organism.

The canner is chiefly concerned with the high heat-resisting power of the spores ; it is necessary that they should be destroyed, otherwise development into the vegetative form may occur in the can, to the detriment of the food contents.

When a spore finds itself in a suitable medium for germination, the spore wall softens and moisture is absorbed ; this results in the development of a living cell which will lengthen and divide in the usually observed manner. The actual manner of germination of a spore is for the growth of the bacillus to occur from one end ; the end appears to open, and the young cell pushes out in the long axis of the spore. Spores sometimes appear to split into halves.

Bacterial Composition

The chemical composition of bacteria depends to a considerable extent upon the nature of the medium in which they are growing ; water makes up a large percentage of their composition, and averages from 60 to 85

per cent., protein matter from 10 to 15 per cent., mineral matter about 1 per cent., and fat from 1 to 4 per cent. They all contain one or more soluble ferments of an enzymic character, which can be extracted. It should be noted that bacteria contain a considerably larger percentage of nitrogen than do the higher vegetable orders ; and, of course, as they contain no chlorophyll they are unable to obtain their supply of carbon from carbon dioxide, and must therefore depend upon other carbon compounds for their requirements. Neither is atmospheric nitrogen available to them. The supply of nitrogen is derived from the proteins of animal and vegetable matter upon which they live. Oxygen is obtained from the atmosphere in the case of ærobes, but from organic compounds in the case of anærobes. There is, however, the class of facultative anærobes which are able to utilise both sources of oxygen.

Bacterial Behaviour

Many of the organisms which are the cause of spoilage in canned goods are either anærobes or facultative anærobes.

Bacteria are capable of resisting great degrees of cold, and temperatures as low as — 190° C. have been found to be insufficient to destroy many species, but of course microbial activity is entirely stopped at these extremes of cold. Temperatures of about — 3° to — 5° C. slow down, but do not entirely arrest growth, and for this reason chilled meat cannot be kept indefinitely without some decomposition taking place.

The thermal death-point of most vegetative forms seldom exceeds 70° C., but the spores are much more resistant, and their behaviour under conditions of heat calls for further comment. Organisms are known— e.g., the *Bacillus Thermophilus* of Miquel—which actually thrive at 70° C. Thermophilic organisms are apt to cause much trouble in a canning factory if once they become established on the surface of the tables or utensils used in the preparation of the food.

Anærobes and facultative anærobes are particularly prone to give rise to trouble in canned goods. All of them, with the possibility of one exception, fall into the spore-bearing class, and the spores of many varieties possess high thermal death-points. The conditions existing inside an hermetically sealed container are favourable for their development, since there is either an absence, or great shortage, of free oxygen. The majority of facultative anærobes produce an abundance of gas in a short time, because, in their struggle for existence, they tear down the organic compounds of which the canned material is composed in order to obtain the small quantity of oxygen necessary to them, and, in doing so, liberate gaseous products which, not being required by the organism, rapidly produce a pressure in the can. For this reason a faultily processed can often shows a more highly blown condition than does one to which traces of oxygen can gain access ; in the latter there is much less need

for the bacteria to attack rapidly the organic matter of which the food is composed.

According to Savage,[2] many samples of canned foods examined were found to contain sporing ærobes, but, in spite of this, the contents were quite sound and showed no signs of decomposition. He explains it by stating that the organisms are present in the form of spores, which on account of the absence of oxygen remain dormant and therefore cause no action upon the food material. We have never been able to confirm Savage's findings, and over 99 per cent. of canned foods which we have examined because they were found to contain organisms in a vegetative state, or spores, showed abundant evidence of decomposition or some spoilage.

Avoiding Spoilage

It is obvious that the manufacturer of canned foods must endeavour to ensure that his finished products shall not contain organisms or spores of any kind whatsoever, whether ærobic or anærobic in character (with the possible exception of fruit). In order to achieve this end two important points have to be observed ; firstly, to avoid by every possible means unnecessary contamination of the raw materials ; and secondly, to carry out the heat sterilisation process at the highest possible temperature that the article will stand without spoiling its palatability. The latter is by no means easy to accomplish, for quite a number of delicate foods will not stand a temperature of 250° F. even for a short period. The prolonged heating necessary at lower temperatures is almost, if not quite, as destructive. When the matter of thermal death-points comes to be discussed it will be noted that not many of the most commonly occurring organisms need quite such a high degree of heat as 250° F., and if great care has been taken in the preparation of the raw materials so as to avoid undue spore formation, slightly lower temperatures of processing will suffice to bring about sterility of the pack, but only when *clean fresh* materials are used.

In a clean and well-conducted food factory, spoilage through the activities of bacteria should be almost unknown, but occasions do arise when, in spite of the care exercised, trouble occurs, usually through infection by a single variety of bacteria, the source of which is, more often than not, extremely difficult to trace. No food canning factory is able to produce all the materials that it requires, and bacterial infection is sometimes introduced in or upon goods brought on to the premises from an outside source. This type of infection must not be confused with that which arises through the faulty and uncleanly handling of the raw materials, for this invariably shows contamination with a mixed flora of bacteria, and can usually be traced to its source by a searching scrutiny of premises, utensils, etc.

When trouble arises the obvious steps to be taken are to identify the organism, or organisms, responsible, to trace the source of the contamination, and to remove it at the earliest possible opportunity. Although it sounds comparatively simple to do these things, in reality it is frequently a task of much difficulty. Nearly all bacteria produce strains not true to type, and when these strains arise, the task of certain identification is difficult, for during the course of sub-culturing in artificial media in the laboratory, the true type may assert itself and mislead the investigator. The authors are acquainted with a case where an infection occurred with an organism of the putrificus group, which is normally anærobic in character, and the spores of which possess a thermal death-point of 230° F. The particular strain which gave rise to the trouble had become converted into a thermophile, the vegetative form of which withstood a temperature as high as 170° F., so that normal methods of cleansing, such as soda and hot water, were ineffective.

Methods of Examination
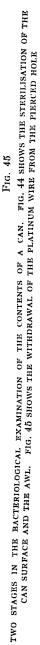
The examination of an unsound can of food should be carried out by the following method :

A Bunsen burner is forced down upon the surface of the tin, and a sterilised awl is put into the flame, and pushed through the tin. A long platinum wire is then sterilised and put down into the can through the hole ; it is then quickly withdrawn and dipped into the appropriate medium—liquid gelatine or nutrient broth—contained in a test-tube, care being taken to prevent the wire from touching the side of the tube. If the material consists of solid matter in suspension in a liquid, such as a meat and vegetable ration, it is necessary to repeat the operation by making additional holes in different parts of the can, as the organisms responsible for the spoilage may not be uniformly distributed. If gelatine is used, this substance can be melted by immersing the tubes in warm water, the temperature of which should not be above 40° C. ; if hotter water is used, then the tubes must be cooled before inoculation. When a tube is to be used, the cotton-wool plug is first singed in the flame, and the tube held between the thumb and first and second fingers of the left hand. The plug is removed by holding it between the third and fourth fingers of the right hand, and the platinum inoculating needle is held like a pen in the right hand. During the time the tube is unplugged it must be held in a slantwise position. The operation being completed, the platinum needle should at once be sterilised by heating to redness in a Bunsen flame.

In order to isolate separate organisms in pure culture, it is necessary to obtain a plate culture upon which only a few colonies are growing, and these few should be separated from one another as widely as possible. If the medium which has been inoculated from the can is plated out, it

Fig. 44

Fig. 45

TWO STAGES IN THE BACTERIOLOGICAL EXAMINATION OF THE CONTENTS OF A CAN. FIG. 44 SHOWS THE STERILISATION OF THE CAN SURFACE AND THE AWL. FIG. 45 SHOWS THE WITHDRAWAL OF THE PLATINUM WIRE FROM THE PIERCED HOLE

Courtesy of "Food"

FIG. 47

FIG. 46

IN FIG. 46, IS SHOWN THE INOCULATION OF THE CULTURE MEDIUM BY THE PLATINUM WIRE. FIG. 47 SHOWS THE TRANSFERENCE OF THE CULTURE TO A PETRI DISH. THE METHOD OF HOLDING THE PLUG AND DISH COVER IN THE LEFT HAND SHOULD BE NOTED

Courtesy of "Food"

[*Facing page* 157

will be found that in nearly all cases it contains a growth much too profuse to allow any separate colonies of organisms to be studied.   It is therefore necessary to sub-culture from the first tube into a second, and third, tube and pour this last into a sterile Petri dish.   In order to bring about this dilution, two medium-sized loopfuls of the original culture are transferred to a second tube, after thorough mixing by using a rotary motion, keeping the tube upright.   The same precautions as those mentioned above are taken in regard to the inoculation of tube No. 2, and this is also well agitated before three or four loopfuls are removed to a third tube.   Tubes Nos. 1 and 2 should preferably contain nutrient broth medium, tube No. 3 either gelatine or agar.   Sometimes both media are used, so that two tubes have to be inoculated from No. 2 sub-culture. The next step is to pour the contents of the No. 3 tube into a Petri dish— which has, of course, been sterilised.   When agar is to be used, the temperature of the Petri dish should be raised to 42° C., otherwise the medium will set before it has spread over the surface of the plate.   If a three-inch dish is used, about 10 c.cs. of medium will be required to produce a reasonably deep layer of agar or gelatine over the entire surface of the plate.   At the time of its inoculation the agar tube should be at a tempera- ture of 42° C.   Under this, the medium will set, above it bacterial growth may be retarded or the organisms killed.   Strict attention to this tem- perature is essential.   When all is ready, the plug of the culture tube is singed in a flame, and the lip of the tube also heated in the flame.   This is necessary in order to guard against contamination of the culture with the outside of the tube.   The lid of the Petri dish is then raised on one side just sufficiently to allow the top of the test-tube to be held over the dish, and the contents quickly poured, when the lid of the dish is at once replaced.   A gentle circular motion may be given to the dish in order to assist in the even spreading of the medium.   The dish is then ready for incubation, and it is advisable to carry out this operation with the dish upside down, because if any moisture exudes from the agar it will form a channel for the diffuse spreading of the colonies, and isolation will be impossible.   When gelatine is used the plates should be left at room tem- perature in a dark place.

When the colonies have developed the dish may be " fished " and this should be done by placing the Petri dish upon the stage of a microscope and examining it with a low-power objective.   The point of the sterile platinum needle is held in the right hand, and directed in the line of the focus of the lens, while the small finger of the hand is steadied upon the edge of the microscope stage.   When the point of the needle is clearly visible through the microscope, it is gently depressed until it is seen to touch the colony and carry away a portion of it.   The needle is then with- drawn, without being allowed to touch again the nutrient medium or the edge of the glass or lens, and is then transferred to a tube of whatever medium is desired.   Every colony which differs in appearance from those

associated with it on the same plate should be treated in this manner, so that a true picture of the bacterial flora present can be obtained.

When dealing with anærobic organisms, the plates must be incubated under the conditions appertaining to this class of organisms.

It will be found that a period of about 48 hours is usually sufficient to allow of the growth of ærobes if they are present, but the anærobic growth is much slower, and in many cases a week or even longer may elapse before growth is evident. If the manufacturing operations have been correctly carried out, and if the precautions in regard to cleanliness have been strictly adhered to, certainly not more than one sample in every thousand examined should show evidence of bacterial growth. When this does happen, steps should be taken to identify the organism or organisms present, and if possible to trace the source of contamination. It sometimes happens that the can which has been examined is a "leaker," due to faulty manufacture or rough handling, but more often the trouble will be found to be due to uneven heat distribution in the retort, whereby some of the cans or glasses have not received the correct process, and at some portion—probably the centre—the temperature has failed to reach the thermal death-point of the organism or its spores.

The above remarks in regard to the sterility of the pack do not necessarily apply to acid fruits or such articles as tomatoes, because the relatively high percentage of acid in such material does not call for complete sterility. The inhibiting action of the acid upon bacterial growth is such that the goods will keep for a prolonged period, although they may not be sterile.

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[1] Duckwell, " Canning and Preserving," National Canners' Association.
[2] Savage, " Canned Foods in Relation to Health," 1923.

CHAPTER X

Preparation and Use of Culture Media

Before entering upon a description of media and the methods of preparation it is desirable to give some consideration to the factors upon which the growth of bacteria depends.

Essentials of the Medium

To a large extent the successful cultivation of bacteria in the laboratory rests on the closest possible imitation of the natural conditions under which the organisms multiply with the greatest ease. For this purpose a medium must contain the proper food supply. For ærobic cultivation, oxygen in the form of air must be available, and also oxygen in combination with other elements of an organic nature. This combined oxygen is also necessary for anærobic reproduction, but oxygen gas as such has to be excluded. The medium must contain a sufficiency of water. The acidity or alkalinity must be accurately controlled. Most organisms prefer a neutral p_H 7·0 medium, or one that is very slightly acid, p_H 6·5 to 6·0. Incubation of the inoculated medium must take place at the correct temperature. Usually the range is fairly wide, except in the case of certain of the thermophilic organisms, when high temperatures, 50° to 55° C., are needed.

Prior to inoculation, sterilisation of the medium must be carried out. This process varies considerably according to the nature of the medium, and attention will be drawn to this point where necessary. When sterile, precautions must be taken to prevent bacterial infection from outside sources.

The chief natural function performed by bacteria is the breaking down into simpler substances of the complicated organic compounds which form the bodies of plants and animals. The food of bacteria is therefore of an extremely complex nature. It must consist of the proper sources of nitrogen, oxygen, carbon, hydrogen, and inorganic salts. Because of its complexity it is seldom possible to produce in the laboratory the natural food environment of any species, for many varieties of microorganisms will nearly always be found growing side by side, and the food supply of any one particular variety is probably altered by that of the others present. It often happens that a particular strain of an organism will not grow satisfactorily except in the particular medium in which it has been found. For example, when dealing with bacteria in canned

159

salmon, it is common practice to prepare a medium into the composition of which the liquor from a can of salmon enters. In fact, in many cases satisfactory identification can only be achieved by following this method.

Three simple media provide a suitable food supply for many kinds of bacteria. Not only do they form valuable media in themselves, but they also serve as the basis of many special media.

The chief constituents entering into the composition of the three common media, in addition to gelatine and agar, are meat extract, peptone, common salt, and water.

Peptone. It has been satisfactorily demonstrated that bacteria cannot make use of protein nitrogen in the form in which it is there combined until the proteins have been broken down (that is, hydrolysed) into simpler compounds. As a consequence, use is made of peptone, which is a complex substance containing some of the degradation products of proteins, among which may be mentioned the amino acids. The peptone present in the medium may therefore be regarded as supplying the initial source of nitrogen to the organisms, which, as they grow, break down the protein matter added as meat extract or as gelatine.

Meat Extract. This is an important constituent of the media, and Lemco is now almost universally employed for the purpose. The making of meat extract from fresh meat is a troublesome process, and the strength liable to great variation, depending upon the kind and quality of the meat used, and also upon the technique adopted. By utilising a standard extract, such as Lemco, a much more uniform medium is produced, and time and labour saved. The main function of the extract is to supply nitrogen and some of the mineral salts needed by the organisms.

Gelatine may be defined as an organic colloidal substance of varying chemical constitution, nitrogenous in nature, and prepared by drying the solution obtained as the result of boiling with water suitably prepared bones, skin, and hide fragments. It is desirable to use only high-grade gelatine in the preparation of media, and care should be taken to ascertain that it does not contain more than a trace of sulphur dioxide, which substance, being a germicide, will inhibit the growth of bacteria if present in more than a very small quantity. Gelatine supplies to the medium a source of nitrogen in much the same manner as does meat extract.

Agar. This substance is a carbohydrate, and therefore contains no nitrogen. It is prepared from the stems of various seaweeds, growing on the coasts of the China Seas and possibly elsewhere, and usually known as " Ceylon Moss." Formerly it was the custom to work with the thin dried stem of the seaweed itself, but more recently agar in the form of powder has become available for use, and the powdered form is now more commonly employed. Its chief use in bacteriology is in the production of

solid media which will stand incubation at blood heat, or even higher temperatures, without liquefaction.

Nutrient Broth.   Dissolve 5 grammes of Lemco in about 200 or 300 c.cs. water, by heat, add 5 grammes of sodium chloride and 10 grammes of sugar-free peptone ; boil the mixture for 25 minutes, and then cool and make the volume up to one litre.   It is now necessary to adjust the p_H value of the broth to 9·0.   This can be readily accomplished by taking 10 c.cs. of the broth, adding 5 drops thymol-phthalein indicator, and titrating with tenth-normal sodium hydrate until a blue colour just appears.   From the number of c.cs. of sodium hydrate needed for the 10 c.cs., it is a simple matter to calculate the amount of normal soda required for the litre of broth.   When this has been added, boil the broth for ten minutes for the purpose of throwing down phosphates, which must be removed by filtration.   Then add the necessary quantity of normal hydrochloric acid to bring the p_H to 7·0.   Run the broth into test-tubes (about 4 c.cs. into each tube), plug with cotton wool, and sterilise at 120° C. for 30 minutes.   Or the broth may be stored in flasks, and filled into tubes as required.

Of course, if storage is to be adopted, the broth must be sterilised at the time of making, and again when filled into tubes.   By the first boiling of the broth in alkaline solution the phosphate is removed ; this is impor-tant, as otherwise it will subsequently be precipitated, and produce cloudy medium in which bacterial growth cannot be readily observed.

Nutrient Agar.   To one litre of nutrient broth, prepared as above, add 15 grammes of powdered agar.   The mixture is heated in the auto-clave for about 20 minutes at 115° C., at the end of which time the agar should be completely dissolved.   It is sometimes necessary to clear the preparation by the addition of egg albumen, in which case the white of two eggs is mixed with a small quantity of water and added to the medium, after the latter has been cooled below the coagulation point of the albu-men (50° to 55° C.)   The mixture is then again autoclaved at 105° C. for a few minutes, and allowed to stand for a short period.   It is filtered through a " rapid " filter paper, using a hot water funnel, and the filtrate, which should now be clear, is sterilised for 30 minutes at 115° C.   No adjustment of the p_H should be necessary, for it should have remained the same as that of the nutrient broth employed in its preparation.

Nutrient Gelatine.   Dissolve 110 to 120 grammes of finest quality gelatine in 1,000 c.cs. of nutrient broth, and raise the temperature to boiling point.   Cool until just warm, and then adjust the p_H of the mixture to 7·0.   Attention is directed to this because gelatine nearly always possesses a low p_H value.   The correction of the p_H is to be carried out in the manner described under " nutrient broth."   While cool, add the white of two eggs, previously diluted with a small quantity of water, boil the mixture for 20 minutes, and then filter through a hot

water funnel, using a " rapid " filter paper. Fill into tubes, containing about 10 to 15 c.c.s. (a suitable quantity for Petri dishes) and sterilise on three successive days for 30 minutes at 100° C. The exposure of gelatine to high temperatures, or to prolonged boiling, induces hydrolysis, which spoils its setting properties.

Three separate and successive sterilisations are necessary to remove bacterial spores which may be present, and which will, of course, resist boiling, unless development into the vegetative form has taken place.

In those laboratories where a large and varied bacteriological practice is carried on, it is often desirable to make up media in large quantities and to store them for use as required. When media are to be used shortly after preparation, the utensils holding them may be plugged with non-absorbent cotton wool of the long-fibre variety. But this kind of closure does not prevent some loss by evaporation, and further the mycelia of moulds are capable of forcing their way through the wool plug, and stored media are sometimes spoiled through this cause. Where prolonged storage is required, a good plan is to make use of the specially prepared containers, an illustration of which is shown. These can be obtained in various shapes and sizes, from 1-ounce to 20-ounce. The chief feature is the screw stopper fitted with the usual cork pad, and a special disc of vulcanite-like material, which serves to seal the container hermetically after the final closure. This is placed inside the stopper against the cork lining. The method of procedure is as follows : The container, having received its quota of media, is *very loosely closed* with the screw cap containing the vulcanite pad, and then sterilised. Immediately after sterilisation, and while the temperature is as nearly as possible at the boiling point of water, the cap is screwed down into its final position. Media treated in this manner will keep for an indefinite period. An alternative method is to screw the cap into its final position prior to sterilisation, but this places a considerable strain upon the bottles, and it may also lead to loss of medium through breakage.

Use of Peptone Water

Peptone Water. As this is largely employed as the basis of sugar media, it is important that the peptone used should be entirely free from even a trace of sugar. To prepare, 10 grammes of sugar-free peptone and 5 grammes of pure sodium chloride are dissolved by means of gentle heat in 1 litre of distilled water, and if necessary the p_H of the mixture adjusted to neutrality in the usual manner. Sterilisation is effected by exposure of the medium to a temperature of 120° C. for a period of 10 minutes ; that is, unless the whole quantity is to be utilised for the preparation of sugar media, in which event the sugar solution is added, and the method of procedure given under " sugar bouillon " followed. Media made with peptone water are the following. Reference will be made to them in Chapter XII.

FIG. 48

SPECIAL CONTAINER FOR THE STORAGE OF MEDIA. IT HAS A SCREW
STOPPER FITTED WITH THE USUAL CORK PAD AND A DISC OF
VULCANITE-LIKE MATERIAL WHICH SERVES TO GIVE A HERMETIC
SEAL AFTER THE FINAL CLOSURE

Courtesy of " Food "

As the presence of only a single sugar is necessary, it is desirable to employ peptone water as a basis, in place of nutrient broth, which is likely to contain some sugars derived from the muscular tissue (hydrolytic products of glycogen, dextrin, maltose and dextrose). Sufficient sugar is added to the peptone water to give a concentration of 1·0 per cent. The medium is then placed in Durham tubes and sterilised either by the intermittent method or for 15 minutes at 105° C. Overheating must be avoided, as the medium will turn brown due to the formation of caramel from the sugar. Stitt[1] states that " it is now considered essential that the sugar solutions, in 20 per cent. strength, should be sterilised separately, and then added to the sterile bouillon, in the correct amount to produce a final 1·0 per cent. solution." This does not appear to be the common practice of the majority of workers in this country, and we have never found it necessary to adopt this additional and somewhat troublesome step. It should be noted that maltose is very readily decomposed, and where it is being used it is preferable to adopt the three-day method of sterilisation.

Sugar Bouillons. These are largely used for determining fermentation. It is important that the sugars employed should be pure, and free from contamination with foreign sugars. Those which are in common use are lactose, maltose and cane sugar (disaccharoses), glucose and galactose (monosaccharoses) and dextrin (polysaccharose). The alcohol mannite is occasionally used, particularly for the differentiation of various strains of dysentery.

Lactose-Bile-Salt, Litmus-Peptone Solution.

Peptone	20 grammes
Sodium taurocholate	5 ,,
Distilled water	1,000 ,,

Dissolve and raise to boiling point, at which temperature the solution should be maintained for 20 minutes. Cool, adjust the reaction to p_H 7·0 by the addition of N /1 potassium hydrate, again raise to boiling point, and hold there for 5 minutes ; then add 10 grammes lactose and about 3 c.cs. litmus solution, or enough to give the medium a distinct purple tint.

Neutral Red Lactose Bile-Salt.

Peptone	20 grammes
Sodium taurocholate (bile salt)	5 ,,
Agar-agar	20 ,,
Lactose	10 ,,
Neutral red	5 c.cs. of a 1·0 per cent. solution
Distilled water	1,000 grammes

Dissolve the peptone and the sodium taurocholate in 100 c.cs. water, and raise to boiling point. In the remaining 900 c.cs. of water dissolve the agar by the usual process ; then add the peptone solution. Adjust the

p_H of the medium to 7·0 and add the white of two eggs dissolved in water to the cooled medium. Raise the temperature to 110° C., and maintain there for 20 minutes in order to ensure complete coagulation of the egg albumin. Filter through a hot water funnel, using a " rapid " filter paper, and to the filtrate add the lactose and the neutral red solution. Fill into test-tubes, putting about 12 to 15 c.c. in each tube ; plug with cotton wool, and sterilise by raising the temperature to 100° C. on three successive days. When the plates are required, they are sterilised in the usual manner, and poured with the contents of one of the test-tubes.

Methyl-Red Glucose. Glucose broth for the methyl-red test is prepared in the following manner :

Peptone	5 grammes	
Glucose	5	,,
Sodium hydrogen phosphate	10	,,
Water	1 litre	

Dissolve the glucose and the peptone in about 250 c.cs. water, by the use of a water-jacketed saucepan ; filter, cool, and add the remaining 750 c.cs. water. Fill into tubes (6 by ⅝ ins.), placing 5 c.cs. in each tube, and sterilise at 100° C. for thirty minutes on three successive days.

Methyl-Red Indicator.

Methyl-red ..	0·15 grammes
Alcohol (95 per cent.)	400 c.cs.
Distilled water ..	600 c.cs.

Special Milk Media

Litmus Milk. Use fresh milk, and sterilise as soon as possible by heating it for 30 minutes at 100° C. Allow it to stand in a cool place for 24 hours, and remove the separated milk fat. To the residue add sufficient of a 2 per cent. sodium carbonate solution to give the milk a p_H reaction of 7·0 to 7·5. Then add 3 per cent. litmus solution. Fill into 5 or 10 c.c. tubes, and sterilise for thirty minutes at 100° C. for three successive days. Bromo-cresol purple is used by some workers in place of litmus as an indicator ; it is more delicate in its reaction, and practically unaffected by the proteins.

Kulp's Casein Digest Medium.[2] Prepared by Kulp for the purpose of studying *lactobacillus acidophilus* and *Bulgaricus* in milk-canning problems.

One hundred grammes of casein are dissolved in 1,000 c.cs. of sodium carbonate solution. (Kulp does not state the strength of this, but casein is readily soluble in 0·5 to 1·0 per cent. Na_2CO_3, and this will be found a suitable strength with which to work.) 1·5 grammes of trypsin powder are then added, and a small quantity of chloroform as a preservative. This mixture is then incubated for from 24 to 48 hours at blood heat,

and then heated in a double saucepan for the removal of the chloroform. The mixture is then given a slightly acid reaction with dilute hydrochloric acid, and boiled and then filtered.   100 c.c., of the digest and 3 grammes of meat extract are then made up to one litre.   The mixture is then sterilised by the three-day intermittent process at 100° C., for a period of 20 or 15 minutes.

Hydrolysed Casein Medium.[3]   Ten grammes of casein are hydrolysed by treatment with 200 c.cs. of 10 per cent. solution of sulphuric acid. The mixture is heated for 24 hours on the water bath, and then neutralised by the addition of a saturated solution of barium hydrate. By this means the sulphate is thrown down and removed by filtration. Evaporate the filtrate until the amino acids start to crystallise out. Measure the volume of the concentrate and then dissolve half of it in 500 c.cs. of Zipfel's synthetic medium, which has the following composition :

Asparagin	..	..	..	..	..	5·0 grammes
Ammonium lactate		..	..	..	5·0	,,
Potassium acid phosphate			..	..	2·0	,,
Magnesium sulphate		..	..	..	0·2	,,
Water	..	..	..	..	..	1000·0	..

This medium is reported to favour the production of indol.

Sherman and Albus Medium[4] for the cultivation of lactobacilli. This medium has the following composition :

Lactose (or other carbohydrate)				1·0 per cent.
Peptone	..	..	..	.	1·0	,,
Dried yeast ..	..	..	.	1·0	,,
Butter fat ..	..	..	.	1·0	,,
Agar	..	..	..	.	0·1	,,

Adjust reaction to 6·5 to 7·0 p_H.
Sterilise at 105° C. for 20 minutes.

Casein Agar.[5]

Casein Solution.

Distilled water	..	..	..	..	300 c.cs.
Casein	..	..	..	..	..	10 grammes
Normal sodium hydrate solution		..	7 c.cs.

Agar Solution.

Distilled water	..	..	..	..	500 c.cs.
Agar	..	..	..	..	..	10 grammes
Casein	..	..	..	..	..	10 grammes
Normal sodium hydrate solution		..	7 c.cs.

Dissolve casein by boiling, make up volume to 500 c.cs. and bring the reaction of the solution to be equal to 1 c.c. to 1·5 of normal hydrochloric acid per litre.

The agar solution is prepared by dissolving 10 grammes of agar in 500

c.cs. water, filtering and mixing solution with the filtered casein solution as prepared above. Tube and sterilise at 115° C. for 20 minutes, and cool the tubes rapidly in cold water. The final reaction of the medium should be p_H 6·5 to 6·0. It must not be alkaline, or the growth of the organisms will be inhibited. If it is too acid, some of the casein will be precipitated on sterilisation. The quantities given above are sufficient to produce one litre of the finished medium. This is a particularly useful medium when it is desired to plate out organisms which prefer milk products for their reproduction. If desired, a small quantity (1 per cent.) of lactose may be added. If this addition is made, the temperature of sterilisation should be modified in order to avoid any decomposition of the carbohydrate.

Liver Broth Medium.[6] This medium was prepared for the study of thermophilic organisms in canned foods. Its method of preparation is as follows :

Five hundred grammes of finely chopped beef or calf's liver are boiled with 1,000 c.cs. of water for 90 minutes. At the end of this period most of the solid matter is removed by straining through fine muslin ; the filtrate is made up to the original volume (1 litre) ; and 10 grammes of peptone are added, together with one gramme of potassium or sodium acid phosphate. The reaction is then adjusted to p_H 7·0. A small quantity of the finely ground boiled liver is added to every 5 c.c. tube, and sterilisation is carried out by autoclaving at 120° C. for 15 minutes.

Nitrate Broth. This is used for the detection of nitrate-reducing organisms, and is particularly applicable where canned cured meat is under examination. It is essential that the nitrate used shall be entirely free from even a trace of nitrite.

To one litre of distilled water, add 1·5 grammes peptone and 5 grammes meat extract. When the peptone is in solution, add 0·25 grammes of nitrite-free potassium or sodium nitrate. Sterilise tubes at 120° C. for 15 minutes, using 4 or 5 c.cs. for each tube.

Care must be taken to test the distilled water used for traces of nitrite, because this substance is frequently found to be present in distilled water which has been standing even for a few hours in the laboratory, particularly where it is the custom to smoke. If nitrite is found in the water, clear tap water may be substituted, but this also must be examined for traces of nitrite.

Trypsin Broth. This medium is usefully employed where slow-growing organisms are under cultivation, because trypsin hydrolyses some of the complex protein substances and thus renders them more available to the bacteria. Gordon, Hine and Flack[7] prepare the medium as follows :

Take 500 grammes of finely minced bullock's heart, free from fat and vessels. Add to this 1 litre of distilled water, and render faintly alkaline to litmus with potassium hydroxide solution. Heat slowly, maintaining

the temperature from 75° to 80° C. for a period of not more than 5 minutes. Cool to blood heat, and then add 10 c.cs. of liquor trypsin compound, transfer to incubator at 37° C., and leave for three hours. Test for peptone in the mixture ; then render just acid with acetic acid, and raise to boiling point, at which temperature maintain for 15 minutes. Allow to stand overnight, and then decant the clear liquid. Make just alkaline to litmus, and sterilise at 118° C. for 60 minutes upon two successive days. This medium will be found particularly helpful in the cultivation of anærobic spore-bearing organisms.

Sulphite Iron Medium. The primary use of this is for the study of bacteria causing sulphite spoilage of canned vegetables.[6]

For 1 litre : 1 gramme sodium sulphite, 30 grammes sucrose, 15 grammes agar, 1,000 grammes nutrient broth.

Dissolve the agar in the nutrient broth, and to the solution add the sucrose and sodium sulphite. Adjust p_H value to 7·0. Tube into 10 c.c. tubes, and add to each tube a piece of iron wire of heavy gauge, about ¾ inch long, or an iron nail. The piece of iron must be completely immersed in the medium. Autoclave at 100° C. for 15 minutes on three successive days. The iron wire or nails should be freed from grease by washing with carbon tetrachloride or other suitable solvent, and then by immersion in dilute hydrochloric acid for a short period. Finally wash thoroughly with distilled water. If preferred, the agar may be dissolved in yeast water instead of nutrient broth.

Yeast Water. This is prepared by digesting in an autoclave at 120° C., for five hours, a 10 per cent. suspension of starch-free yeast in distilled water. The digest is then stood aside for five or six days, or until clear, when the supernatant liquor is siphoned off and used without filtration.[8]

Linden[15] classifies acid canned food into five general groups (1) tomato products, (2) fruit and fruit products, (3) fermented foods, (4) marinated foods and (5) beverages.

He considers the following media suitable for the examination of such food :

*Tomato Juice Broth.**
   Nutrient broth .. .. 900 c.cs.
   Tomato juice or tomato pulp .. .. 100 c.cs.
Reaction p_H 6·8 to 7·2.

Tomato Juice Agar (Dehydrated).
   Tomato juice (400 c.cs.) .. .. .. 20 grammes
   Peptone .. .. 10 „
   Peptonised milk .. .. 10 „
   Agar .. .. 12-15 „
   Water make up to .. .. .. 1000 c.cs.

* Place the material in Durham fermentation tubes. Sterilise under 10 lbs. pressure for 15 minutes.

Pederson's Yeast Water-Tomato Juice.*

Yeast water	900 c.cs.	
Filtered tomato juice	100 c.cs.	

Adjust reaction to p_H 6·6 to 6·8.

Trypsin Digest Agar.

Trypsinised milk	20	grammes
Tomato juice	10	,,
Peptone	8	,,
Dextrose	4	,,
Dextrin	4	,,
Agar powdered	13–15	,,

Final p_H 6·1 to 6·2.

Dissolve 59 grammes of the powder in 1,000 c.cs. of distilled water by
boiling. Tube and autoclave at 15 lbs. pressure for 15 to 20 minutes.

Cameron[16] gives particulars of special media used in connection with
the examination of non-acid canned products.

Dextrose Tryptone Agar.

Tryptone	10	grammes
Dextrose	5	,,
Agar	15	,,
Bromocresol purple	0·04	,,
Water	1000	,,

On account of the presence of dextrose in the medium it should be
sterilised by the intermittent method (3 times at intervals of 24 hours
at 100° C.).

The medium is recommended for the cultivation of flat sours, and
incubation after inoculation should be at 55° C.

Use of Potato Tubes

Potato Tubes. These may be prepared by cutting thin wedge-shaped
slices of potato of such a size that they will slide into a test-tube ; at
the bottom of the tube is placed a small piece of glass rod or glass bead,
together with a small piece of cotton-wool covered with water, the purpose
of the latter being to keep the medium in a moist condition. Sterilise
in the autoclave for 40 minutes at 121° C. The piece of potato should be
of sufficient length to lie slantwise in the tube to produce a surface not
unlike an agar slope. If preferred, special tubes containing a restriction
about 1 inch from the bottom may be used. This serves as a ledge upon
which the potato rests.

A semi-fluid potato medium may be prepared by digesting 100
grammes of mashed potato with 800 c.cs. of distilled or tap water. The
digest is boiled for 30 minutes, and then strained through muslin. To

* The yeast water is prepared in the manner described on page 167 and then placed in
Durham tubes and the tomato juice added just prior to sterilisation which is carried out
in an autoclave at 10 lbs. for 15 minutes.

500 c.cs. of the strained solution add 3·0 per cent. agar and 500 c.cs. nutrient broth.   Sterilise for 40 minutes at 121° C.

Holman's Cooked Meat Medium. This medium was devised by Holman,[9] for the study of anærobes. It is prepared from fresh beef, freed from fat and other gross fibres. The beef is finely minced, ground in a mortar, and mixed with an equal volume of water. It is then slowly heated to boiling, with constant stirring, to allow the soluble albumins to coagulate about the particles of meat. The coagulated albumin serves in itself as a favourable medium for the anærobes, as Tarozzi has shown. The emulsion of meat medium is then neutralised or made slightly alkaline, using hot titration with phenol phthalein, tubed at least two inches high and autoclaved at 115° C. for at least 30 minutes.[10]

Cooked Meat Medium.   500 grammes of fresh beef-heart are finely minced, and digested with 10 grammes of peptone in 1 litre of water. The mixture is then allowed to simmer in a double saucepan for 10 to 15 minutes, and the reaction is adjusted to p_H 7·2. The cooking is then continued for 1½ hours, and the reaction readjusted to p_H 7·2 if necessary. The broth is then decanted, and the particles of meat placed in test-tubes of 16 to 17 mm. internal diameter.   After autoclaving these tubes and the broth in separate containers for 15 minutes at 15 lbs. pressure, the broth is added to the meat tubes in 5 c.c. amounts.   The tubes are then heated to 100° C. on two successive days for a period of 20 minutes.   This method prevents the fluid being forced up into the cotton-wool plug ; this is liable to happen if the fluid and meat are autoclaved together.

Stock Cultures

Medium for Stock Cultures.[11] The medium has the following composition :

Meat infusion.

Peptone	1·0 per cent.
Gelatine	1·0
Casein (pure)	0·5
Glucose	0·05
Disodium hydrogen phosphate	0·4
Sodium citrate	0·3
Agar	0·75

Ayres and Johnson suggested the following method for the preparation :

(a)

For one litre.

Meat infusion broth	500 c.cs.
Peptone	10 grammes
Sodium phosphate	2 grammes

Warm until solution is effected, then adjust p_H to 7·8.

(b)

Distilled water	..	..	..	150 c.cs.
Casein (Hammersten's)	..	..	..	5 grammes
Sodium phosphate ..	..	..	..	2 grammes

Warm until solution is effected, then mix (a) and (b), and add 10 grammes of gelatine.

(c)

Heat the mixture and autoclave for 10 minutes at 15 lbs. pressure; then add 0·5 gramme glucose, adjust reaction to p_H 7·6, and filter.

(d)

Prepare 250 c.cs. of 3·0 per cent. agar, filter, and dissolve in the filtrate 3 grammes of sodium citrate.

(e)

Mix (d) and (c) and make up to 1 litre. Tube and sterilise for 20 minutes at 121° C. A slight precipitate may be formed, but this will be found to dissolve in a short time. The final p_H of the medium will be 7·5.

The sodium phosphate used should be the usual $Na_2HPO_4 \cdot 2H_2O$.

The Ayres and Johnson medium will be found suitable for use where the maintenance of stock cultures in as vigorous and unchanged condition as possible is required.

Its preparation is somewhat troublesome, and Worth's[12] medium may be substituted for it. The author describes its preparation as follows: Heat 500 grammes of chopped beef in 1 litre of water at 50° to 55° C. for 1 hour, strain through fine muslin, and make volume of filtrate up to 1 litre. Add to this 10 grammes peptone, 5 grammes salt, and 10 grammes gelatine. Heat until dissolved, adjust p_H to 1·0 per cent. acid, filter, and sterilise at 110° C. for 20 minutes.

In a laboratory where a comparatively large number of stock cultures have to be kept in active condition, a medium of this nature is very necessary.

Corn Liver Medium. Intended for the detection of thermophilic anaerobes, not producing hydrogen sulphide. McClung and Mecoy[17] describe its preparation as follows: The medium is made from ordinary whole corn meal, dried liver and water. The one or two per cent. liver (tissue from liver infusion medium dried at 55° to 60° C. and finely ground) and 5 per cent. corn meal are steamed for one hour, cooled and tubed. The resultant rather viscous medium requires care in sterilising; this may be accomplished by autoclaving for 2 hours at 15 to 17 lbs. If pressure is reduced slowly after sterilisation, short (6-inch) tubes may be used without blowing the plugs. This medium need not be steamed just before using, requires no seal nor incubation in an anaerobic jar,

and satisfactory results may be obtained with 2 to 5 centimetres depth of medium.

Positive cultures are recognised by the appearance of gas with or without digestion of the medium. There may also be a measurable change in the reaction of the medium.

Sulphite Agar. Intended for the detection of thermophilic anaerobes producing sulphuretted hydrogen. (*Cl. nigrificans.*)

This medium is prepared by adding 0·1 per cent. sodium sulphite and 3 per cent. sucrose to plain yeast-water agar. At the time of tubing a clean iron strip or nail is placed in the tube. The medium should be used within a week of its preparation. Yeast water is prepared by autoclaving at 15 lbs. pressure for 5 hours a 10 per cent. suspension of starch-free yeast. This is allowed to settle for several days. When clear the supernatant liquid is decanted and made into a medium containing 1·5 per cent. agar. The reaction is adjusted to p_H 7·0.

In sulphite agar the sulphide spoilage organisms are detected through the formation of characteristic blackened spherical areas. Due to the solubility of sulphuretted hydrogen and its fixation by iron no gas is noted. Certain of the thermophilic anaerobes not producing sulphuretted hydrogen give rise to relatively large amounts of hydrogen, which splits the agar and reduces the sulphite, thereby causing general blackening of the medium. This condition, however, is readily distinguishable from the restricted blackened areas mentioned previously. The blackened areas may be counted upon to obtain quantitative results.

Dilute Agar for Anærobic Cultivation. A useful medium which serves for the propagation of many anærobes may be made by dissolving 0·3 per cent. agar in nutrient broth, tubing in 10 c.c. quantities, and sterilising at 121° C. for 15 minutes. Upon cooling, the medium should have the consistency of a very weak jelly.

Blood Agar. This medium, which is employed for the detection of hæmolytic streptococci, is made by heating in a flask 100 c.cs. of nutrient agar medium. Heat is applied until the agar is melted, and then cooled to 50° C. 1 c.c. of defibrinated human or rabbit's blood (obtained under conditions which ensure its sterility) is added for each 10 c.cs. of agar in the flask, and the mixture thoroughly agitated. About 10 to 12 c.cs. are used for each plate. Surface streaks are made, and the plates incubated for 24 hours at 37° C. Isolated colonies are then studied.

When it is desirable to incorporate some of the contents of a can of spoiled food with a medium, it is usual to add to nutrient broth about 5 per cent. of the liquor from the can, and then to sterilise the mixture at a temperature of 121° C. for a period of 20 minutes. In most instances it is unnecessary to adjust the p_H of the mixture before sterilisation, unless the contents of the can have been found to be markedly alkaline or acid. It is, however, important to incubate tubes after planting

ærobically and anærobically, because organisms of both these types are likely to be present, or the cause of the spoilage may be due to the action of a single variety. By employing some of the material from the spoiled can in the medium, much time and trouble can frequently be saved, because bacteria invariably grow more rapidly in the environment to which they have been accustomed.

Cultivation of Anærobes

There are several methods in use for the cultivation of anærobic organisms, which are frequently the cause of spoilage in canned food and must therefore be looked for in the routine samples. For this reason a simple method is to be desired, and that of Tarozzi[13] will be found suitable. In this method, pieces of fresh sterile kidney, liver or spleen are added to nutrient broth. After adding the tissue the medium should be heated to 80° C. for four or five minutes. This may be done without interference with the anærobic-producing properties of the fresh tissue. Other means of cultivating anærobes are :

Novy's Jar. The principle of this is the replacement of the oxygen by hydrogen in a specially constructed jar. This is made in two pieces which fit together by means of a ground joint flanged to permit of the use of clamps. The upper half of the jar is fitted with two tubes which serve respectively as inlets and outlets for the gas. The test-tubes containing the medium inoculated with the organism are placed in the jar, which is then clamped securely and connected with the hydrogen generator. This latter can conveniently be a Kipp, but unless pure arsenic-free reagents are used for the production of the gas, this must be washed by passing through silver nitrate solution for the removal of arseniuretted hydrogen, and through lead acetate solution for the removal of sulphuretted hydrogen. The stream of hydrogen must be continued until all the air has been removed from the jar.

A modification of the above apparatus is that devised by McIntosh and Fildes.[14] The method depends upon the action of hydrogen upon platinised asbestos, or asbestos treated with palladium. When the hydrogen is allowed to enter the jar in its passage over the treated asbestos, oxidation occurs at the expense of the oxygen in the apparatus. There are two disadvantages attached to this apparatus : (1) If the hydrogen is allowed to enter too rapidly an explosion may occur, and (2) the heat generated renders it unsuitable for use with gelatine cultures. The apparatus consists of a glass jar fitted with a metal lid, which can be clamped into position. The lid carries a stopcock which communicates with the interior of the jar, where it supports a capsule of fine copper gauze containing a piece of palladium or platinum asbestos about one inch square. The copper acts as a heat conductor to prevent the asbestos reaching too high a temperature during the burning of the oxygen.

When the jar is to be used, the cultures having been placed inside it, the gauze capsule is heated to redness in a Bunsen flame, the lid fixed in position, and the stopcock at once connected with the hydrogen generator.   After all the oxygen has been removed, the jar is allowed to cool, the stopcock is closed and disconnected from the hydrogen generator ; the apparatus may now be placed in the incubator.   It will be gathered from the above that both these methods are rather cumbersome where routine testing has to be adopted, and therefore that devised by Tarozzi is to be preferred.

There is another method which is simple and quite effective for the growth of anærobes.   A small quantity of pyrogallic acid is placed in a jar of sufficient dimensions to hold the culture tubes, which are then stood in the jar ; caustic soda solution is added, and the apparatus is quickly closed by a well-fitting stopper.   The alkaline pyrogallol removes the oxygen from the air contained in the jar and tubes.

A rough and ready method is to pour some liquid paraffin upon the top of the medium, by which much of the air is excluded from the culture, and the tubes can be incubated without special apparatus.

When identification of organisms which possess gas-producing or fermentative properties has to be done, it is necessary to prepare sugar bouillon, lactose and glucose being the two sugars most commonly employed.   The medium is made by adding 1·5 to 2 per cent. of the sugar to nutrient broth prepared in the usual manner, but the temperature of sterilisation should not be allowed to exceed 105° C.   If higher degrees of heat are used, browning of the medium may occur.   Where gas formation is to be looked for, a Durham tube is introduced into the tube of culture medium, with its open end downwards.

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CHAPTER XI

ON account of the transparency of bacteria, it is usually not possible to examine cultures satisfactorily unless the organisms have been stained. This operation is therefore of great importance to the bacteriologist, and needs a considerable amount of practice in order that the operator may become expert, and thus be able to reap the full advantage of a microscopical examination.

The fact that many of the coal-tar derivatives of the basic aniline group possess a strong affinity for bacterial protoplasm, makes it possible to use solutions of these dyes for staining purposes, but some of the dyes are so readily taken up by bacteria that unless care is exercised overstaining may result.

Two methods of staining are commonly employed. In the former the staining is carried out upon the cover glass ; in the latter upon the slide, which, being larger in size and less fragile, is more easily handled, but on the other hand is more troublesome to dry and stain, for unless care is taken the stain is liable to spread itself over a much larger region of the slide than is desirable.

The first essential, whatever the method used, is to have perfectly clean grease-free slides and cover glasses. The latter, for this class of work, should not be more than 1/200 of an inch thick, and the former should be made from white glass. Both the slides and the cover slips should be immersed in concentrated sulphuric acid for a few hours, which serves the purpose of removing the thin film of grease with which they are ordinarily coated. The glass is then washed with water and treated with a warm solution, about 5·0 per cent. sodium hydrate, again washed, and then rinsed in a mixture of alcohol and ammonia in equal proportions. After this treatment the slides and cover slips should be perfectly clean. They are then transferred to a wide-necked bottle fitted with a ground-glass stopper ; sufficient absolute alcohol is used to cover them completely, and they are thus stored until required for use. When required they should be lifted out with a pair of forceps, gently dried with a piece of clean grease-free silk, and finally passed quickly through a Bunsen flame. The successful staining of films depends to such a large extent upon the clean condition of the slide and cover slip that it is well worth while to carry out in detail the somewhat lengthy and troublesome process set forth above.

Staining on the Cover Glass

A small drop of distilled water is placed in the centre of the glass, which, if properly cleaned, will not allow the water to break up into a number of small droplets : it should remain as a single drop. A very small quantity of the culture under examination is then introduced into the water by means of a straight platinum needle, previously sterilised in a Bunsen flame. It will be sufficient if the wire be allowed just to touch the bacterial growth. When a culture in a liquid medium is under examination, a *very small* loopful is used. The tendency is to get overcrowded slides, in which the study of individual organisms is impossible. It must be remembered that along with the organism a quantity of the medium is also picked up by the wire, and this will take the stain, so that care should be taken not to push the wire into solid medium ; a stroking action is to be preferred.

The drop of water upon the cover slip should now be spread over the whole surface by movements of the wire. It will be found convenient to hold the slip in a pair of forceps (see illustration) during the whole process, until it is ready for transference to the slide. The drop of water containing the culture is now evaporated to dryness ; this may be done by placing the slide in a very gentle heat, not exceeding 50° to 60° C. When quite dry the culture is fixed by passing the slip two or three times quickly through a Bunsen flame, with the specimen side upwards. A small drop of water is then placed upon the specimen, and allowed to flow over the whole surface, and the glass is flooded with an aqueous solution of the dye ; gentle heat may now be applied, although it is not absolutely necessary. Ebullition must be avoided.

The period during which the dye is allowed to remain in contact with the specimen varies to some extent with the stain being used, and judgment should be exercised at this point. As a rule one to two minutes is amply sufficient for carbol fuchsin, and three to four minutes for methylene blue. Overstaining should be carefully avoided ; an overstained film loses much of its clarity of definition, and is therefore useless. If heat has been employed, then the slip should be allowed to cool before the washing away of the excess of dye is undertaken. This may be done by holding the slip in running water. It may then be immersed in dilute alcohol for a few seconds, which will serve the purpose of clearing up the field.

The treatment with alcohol must not be prolonged, as this reagent will remove the stain from the specimen. The alcohol being now washed off, the cover slip is next placed specimen side downwards upon a clean slide, and gently pressed into position so as to remove air bubbles. The excess of moisture is removed from the slide with filter paper. After placing a drop of cedar oil in the centre of the cover glass, the stained culture may be examined through the 1 /12 objective.

Staining on the Slide

Select one of the specially cleaned slides, place in the centre of it a small drop of distilled water, and then introduce into the drop a very small quantity of the culture under examination, the same precautions being taken as in cover slip staining. In order to prevent the water spreading too much over the surface of the slide, it may be confined by drawing across the slide two lines with a grease pencil, the space in between the lines being wide enough to admit a cover glass. The culture having been introduced into the drop of water, the slide is subjected to very gentle heat in order to assist evaporation of the water, the specimen side being remote from the flame. If care is taken, the warming may be done by holding the slide in the fingers well above the top of a small Bunsen flame. If the slide is held in the fingers, there is little risk of over-heating. When the preparation is quite dry, the film is fixed by passing the slide two or three times through the Bunsen flame. A small amount of the stain is now allowed to drop on to the film and to remain there for a short period—from a half to two minutes according to the stain in use and the variety of organism under examination.

The excess of stain is then washed off the slide by holding it in a stream of running water. Then, if desired, the field is cleared by a wash with dilute alcohol, this reagent being removed after a few seconds by water. The cover slip is then dropped into position, air bubbles squeezed out by gentle pressure, the excess of water removed with filter paper, and the slide is then ready for microscopical examination. Some workers do not employ cover slips when staining on the slide is employed, unless it is intended to make a permanent preparation, in which event a cover slip is a necessity.

Gram's Method of Staining

This is the most important method of staining in bacteriological technique. It serves the purpose of dividing micro-organisms into the two classes " Gram-positive " and "Gram-negative." The films are first stained with aniline gentian violet, and then exposed to a solution of iodine. An attempt is then made to decolorise the stained organism with alcohol. If the dye is thus removed, the culture is considered to be " Gram-negative." If the colour remains, the culture is " Gram-positive." If the film under examination consists of more than one variety of bacterium, one of which is Gram-negative, after the removal of the dye from it, it is usual to counter-stain with weak carbol fuchsin. A considerable amount of experience is needed before uniform results can be obtained, and the following points should be kept in mind :

Old or attenuated cultures do not stain with Gram preparation satisfactorily.

FIG. 49

SHOWING THE METHOD OF HOLDING THE COVER SLIP, BY MEANS OF
A PAIR OF CORNET'S FORCEPS, UNTIL READY FOR TRANSFER TO
THE SLIDE

Courtesy of " Food "

Aniline gentian violet rapidly deteriorates when exposed to light ; it should be kept in the dark.

The iodine solution also becomes light in colour with age, and a fresh preparation should therefore be made frequently.

Decoloration with alcohol should be stopped as soon as no more violet stain can be seen leaving the film.

Weigert[1] recommends the following stock solution :

No. 1 Solution.

Gentian violet	2 grammes
Aniline oil	9 c.cs.
Alcohol (95 per cent.)	33 c.cs.

No. 2 Solution.

Gentian violet	grammes
Distilled water	100 c.cs.

To prepare the stain, mix 1 c.c. of No. 1 with 9 c.cs. of No. 2 and filter.

Gram's Iodine Solution.

Iodine	1 gramme
Potassium iodide	2 grammes
Distilled water	300 c.cs.

Carbol Fuchsin Counter-stain.   Dilute strong solution to 1 in 10.

Technique of Staining

The film is fixed by heat according to the methods previously detailed, and then stained with the gentian violet preparation, the stain being allowed to remain on the film for three minutes. The stain is then poured off, and the iodine solution added, and then allowed two or two and a half minutes' application. After this treatment the preparation appears very dark or almost black in colour.

The removal of the colour with absolute alcohol is the next step. In order to bring this about, the alcohol should be applied in very small quantities, preferably drop by drop until, on gently rocking the slide, no more dye can be observed to wash away from the film. The pre-paration is then at once washed with water. As a general rule it takes about 1½ minutes to bring about decolorisation, but if foreign material is present on the slide (such as minute specks of agar or gelatine) it is rather difficult to know when the colour has been removed from the bacteria. Those organisms which have failed to retain the dye will remain a faint dirty grey colour when viewed under the microscope. The film is now washed with water, and then counter-stained with the dilute carbol fuchsin solution, which is allowed to remain on the slide for about 45 seconds or a minute. The slide is again washed, and prepared in the usual manner for microscopical examination. The Gram-positive organisms will appear a deep violet in colour ; those which are Gram-negative, if present, will be stained red with the carbol fuchsin.

Preparation of the Common Staining Solutions

Carbol Fuchsin.   Dissolve 1 gramme of granulated fuchsin in 25 c.cs. of absolute alcohol ; allow the solution to stand for 12 hours ; then add 100 c.cs. of a 5 per cent. solution of phenol.   Filter and place in a stoppered bottle.   If the solution does not remain absolutely clear, it must be filtered again before use.   It is a common practice to pour a small quantity of the dye solution through a filter paper, and allow the filtrate to drop upon the slide to be stained.

Alkaline Methylene Blue.   Make a saturated solution of methylene blue in absolute alcohol, and to 50 c.cs. of the solution add 120 c.cs. of an aqueous solution of potassium hydrate, containing 0·01 grammes per 100 c.cs.   Filter and store in a stoppered bottle.   Again filter on to the preparation as described under carbol fuchsin.   The methylene blue is a useful stain for general use.   It does not stain the film so rapidly as carbol fuchsin, and when it is employed at least three minutes' exposure of the culture to the action of the dye is required before the latter is removed by washing.   Because of its relatively slow action, there is less danger of over-staining with this dye than with the fuchsin.

Carbol Gentian Violet.   To 10 c.cs. of a saturated solution of gentian violet in absolute alcohol add 100 c.cs. of a 5 per cent. solution of phenol. This stain, whilst not of quite such general use as carbol fuchsin and methylene blue, will be found to give very excellent results with organisms of the *B. subtilis* type ; it usually produces a very clean and well-defined field.

Spores

Spores are difficult to stain, and their presence upon a slide can usually be microscopically identified because they have not taken up the stain. If for special reasons it is desired to stain them, the following method may be employed :

The films are fixed by heat, and then treated with 10 per cent. caustic soda solution for five minutes.   They are afterwards thoroughly washed in tap water, and stained with hot strong carbol fuchsin solution for five minutes.   They are next washed in water once more, briefly dipped in 1 per cent. sulphuric acid, and returned to the water.   This treatment with acid should decolorise the bodies of the bacteria, leaving the spores stained red.   Finally, the film is counter-stained with methylene blue for half to one minute.   The chief difficulty in the process consists in staining the spores sufficiently deeply to allow the acid to decolorise the remainder of the protoplasm without removing the stain from them also.

Special Methods for the Staining of Flagella

The identification of micro-organisms is often difficult. Indeed, the bacteriologist must sometimes merely satisfy himself that the bacterium falls into a particular class without positively establishing its identity. Because of this difficulty, it is important that any operation which is likely to help in overcoming it should not be neglected, even though it demand much patience and some skill. It has been found from experience that it is quite often helpful to ascertain whether the organism is flagellated, and if so, what type of flagella it possesses. The staining of films for flagella calls for special technique and care, but the information obtained usually fully compensates for the trouble. So far as is known, the possession of flagella is peculiar only to those organisms which are motile of their own volition—a property which can be ascertained by means of a hanging drop culture ; the preparation of this will be described later.

Bacteria differ widely in the number and character of their flagella, and may be divided into : (1) lophotrichous, having a bunch of flagella at one end ; (2) peritrichous, having large numbers of flagella growing out from all parts of the cell, an example being *proteus vulgatis* ; (3) monotrichous, having a single flagellum at one end, as in *cholera spirillum* ; (4) amphitrichous, having a spirillum at each end.

The flagella of different organisms differ not only in the position they occupy, but also in length and shape. Some are extremely fine, some are long and wavy, others are short and nearly straight. Generally, anærobic bacteria possess very curly flagella. It is possible in many instances to classify motile organisms as ærobic or anærobic according to the appearance of the flagella.

Young Cultures Essential

It is essential to work with young cultures; according to Duckwell,[3] the best results are obtained by streaking the surface of a 2 per cent. agar plate with a young culture grown in nutrient broth, never with one grown on agar or gelatine. As a rule, the culture should not be more than 24 hours old at the time of making the microscope slide, but when dealing with a very slow growing type of organism, due allowance must of course be made. The use of 2 per cent. agar in preference to the usual 1·5 per cent. medium is accounted for by the fact that the former being of a stiffer consistency, not so much debris will be picked up by the organism. The presence of more than a trace of foreign matter on the slide will seriously militate against successful demonstration of flagella because it will cling round and quite obscure the very fine thread-like growths.

Cover glasses and slides used for the demonstration of flagella must be absolutely clean. The methods of cleaning must be carried out *in toto* if failure is to be avoided.

According to Mackie and McCartney,[4] a small loopful of a young agar culture is emulsified with distilled water, sufficient only of the culture being introduced into the water to cause a slight turbidity. A loopful of this emulsion is placed upon the centre of the *clean* slide, or upon the *clean* cover slip, and dried in warm air. Over-heating must not occur.

It is sometimes desirable to draw to one side of the slide the excess of the loopful of emulsion which is to be stained, so that a thick part of the film is formed. This operation can be accomplished by careful manipulation of the platinum needle.

Preparation of Slides

There are several satisfactory methods of proceeding with the preparation of the slide, the following being those most commonly in use.

Kirkpatrick's Method.[5]

The following solutions are required :

(1) Fixing Solution.

Absolute alcohol	.. ..	60 c.cs.
Chloroform	.. ..	30 ,,
Formaldehyde	.. ..	10 ,,

(2) Mordant.

Ferric chloride	5 per cent. solution	.. ..	1 part
Tannic acid	20 per cent. ,,	.. .	3 parts

The mordant is diluted with an equal volume of water before use.

(3) Silver Stock Solution.

Dissolve 10 grammes of silver sulphate in 200 c.cs. distilled water, and incubate for 24 hours at 37° C.

(4) Staining Solution.

Place in a 100 c.c. flask, 40 c.cs. of filtered stock silver solution, and add to it rapidly 0·6 c.c. of ethylamine, 33 per cent. weight-volume. (This preparation is made up ready for use by the British Drug Houses, Ltd.) On the addition, a precipitate is produced, which should be removed by a further quantity of the silver stock solution until only a faint opalescence remains. At this stage, add 10 c.cs. of distilled water.

The next step is to add the fixing solution, and allow this to remain in contact with the film for from one to two minutes. Then rinse with alcohol and wash well with water. The mordant is then added and allowed to operate for about five minutes. The slide is again washed, and its underside dried with filter paper. Add a few drops of filtered stock silver solution, warm very gently until the thick part of the film has become dark brown in colour, and a metallic scum appears. This takes about 15 seconds. Allow a further 15 seconds for the silver to act, and then, without further warming, wash off the solution in running water. Dry the film by means of very gentle heat.

If the staining operation has been successfully carried out, the organisms will be black, and the flagella either light brown or grey in colour. A granular appearance is probably due to the use of excess of the ethylamine preparation, to over-heating, or to the use of too much mordant. If insufficient ethylamine be used, the formation of a crystalline deposit may take place.

Casares Gil's Method.[6]   One loopful of an 18-hour growth of the organism on agar is placed in 2 c.cs. of distilled water and thoroughly mixed.   This suspension is incubated for 15 minutes at 37° C.   One loopful is then placed upon a clean slide, and the slide tilted so that the drop runs off, leaving only a very thin film.   Dry in slightly warm air. Mordant.

Tannic acid ..	10 grammes
Aluminium chloride	18 ,,
Zinc chloride ..	10 ,.
Rosaniline hydrochloride	1·5 ,,
Alcohol (60 per cent.)	40 c.cs.

Grind the solid constituents in a mortar with the alcohol, and for use dilute the mordant with two parts water.   Filter a few drops of the mordant on to the slide, and allow this to act on the culture film for from one to two minutes ; during this period a precipitate and a metallic sheen should form.   Wash thoroughly in water, and then cover the preparation with carbol fuchsin solution.   Allow the dye to remain in contact with the film for one minute ; then wash once quickly with alcohol, and finally with water, and allow to dry in air.

Zettnow's Method

Stitt[1] describes Zettnow's Method, and states : " This gives the most satisfactory results of any method I have ever experimented with."   It is carried out as follows :

Zettnow's Method.   In 200 c.cs. water dissolve 10 grammes tannin; warm to 50° or 60° C., and add 30 c.cs. of a 5 per cent. solution of tartar emetic.   The turbidity of the mordant should clear up entirely on heating.   If a small crystal of thymol is added to the solution, it should keep well for months.

In 250 c.cs. distilled water dissolve 1 gramme silver sulphate, and to 50 c.cs. of this solution add drop by drop 33 per cent. ethylamine solution, until the yellowish-brown precipitate which at first forms is entirely dissolved.   The film on the slide, the preparation of which has already been described, is floated in some of the mordant solution contained in a shallow dish, and heated over the water bath for from five to seven minutes.   The dish is then removed from the water bath and as soon as opalescence appears as the result of cooling, the preparation is removed

and thoroughly washed in water.   Add a few drops of the ethylamine silver solution to the film and warm until steam appears and the edge appears black.   Finally, wash in water and mount.   The flagella should appear greyish-brown in colour.

Personally, we prefer the method adopted by the late Professor Duckwell,[3] for we have found that if this be followed in every detail, most excellent results can be obtained.

The method he used for preparing the film is much the same as that described at the beginning of this chapter, but he introduces a special modification when slime-producing bacteria are being dealt with.   The slime collects between the flagella and the mordant fixes the slime as well as the flagella, which are thus entirely obscured.   A very young growth of the organism is used, and loopfuls are transferred to about 1 c.c. of distilled water until the suspension becomes very cloudy.   The slime increases the cloudiness, and this is necessary in order to have a sufficient number of organisms present to make a satisfactory preparation.   The suspension is then shaken with chloroform, which serves the purpose of removing the slime from between the flagella.   The film is then pre-pared from the water suspension which remains above the chloroform. Pigment-producing organisms are treated in the same manner.

The mordant is prepared as follows : Two grammes of desiccated tannic acid are dissolved in 15 c.cs. of distilled water by the application of gentle heat ; to the solution add 5 grammes of a saturated aqueous solution of ferrous sulphate and 1 c.c. of a saturated alcoholic solution of fuchsin.   Add to this preparation about 1 to 1·5 c.c. of a 1·0 per cent. solution of sodium hydroxide.   The mordant is then filtered, giving a slightly turbid filtrate of a reddish-brown hue.   It should be used within five hours of making, after which time it loses its staining power.

A small quantity of the filtered mordant is placed upon the preparation and gently warmed.   Usually, when the mordant is quite fresh, about half to one minute is sufficient to bring about satisfactory staining. Thoroughly wash the preparation in running water, and then add to it a few drops of absolute alcohol, which are at once washed off.   The alcohol will dissolve much of the precipitate which has formed upon the film, but it must be very quickly removed, otherwise it will carry with it the organisms and flagella.   The preparation is then treated with carbol fuchsin solution, this being allowed to remain in contact with it for about 30 seconds.   During this period very gentle heat is applied.   The film is washed and dried by gentle heat and mounted.

The demonstration of flagella calls for experience and skill, and those attempting the operation for the first time must expect to meet with a few failures before success is attained.

Capsule Staining

The cell membrane in many organisms swells to form a capsule,

and on occasion it is necessary to demonstrate the presence or otherwise of a capsule.   This calls for special staining, and the methods described below will be found to give quite satisfactory results.

Hiss's Method.[4]   The following solutions are required :

(1) Saturated solution of alcoholic gentian violet   1 part.
     Water ..   ..   19 parts.

(2) A 20 per cent. solution of copper sulphate in water.

   (*a*) Prepare a thin film of the organism by the usual methods, and fix by gentle heat.

   (*b*) Filter on to the film a few drops of the gentian violet stain, and allow this to act for 15 to 20 seconds at gentle heat.

   (*c*) Wash off the stain with the 20 per cent. copper sulphate solution and dry without the application of water.   In order to avoid the formation of an excessive quantity of copper sulphate crystals upon the preparation, the film should be continuously washed with the solution until it has reached atmospheric temperature.   If the staining has been successfully carried out, the bacteria will appear deep violet in colour surrounded with the light violet capsule.

Muir's Method for Capsule Staining.[5]   This method, though slightly troublesome to perform satisfactorily, produces a really beautiful effect, the bacteria appearing as bright red in colour and the capsules bright blue.

The film is first stained with carbol fuchsin in the usual manner, the preparation being gently heated.   It is then washed with alcohol (95 per cent.), the alcohol being quickly removed, and finally with plenty of water.   The film is then treated with the following mordant for a period of 30 seconds :

Saturated solution of mercuric chloride   ..   2 parts.
Tannic acid 20 per cent. aqueous solution ..   2 „
Saturated aqueous solution of potassium alum   5 „

Remove the mordant by thoroughly washing with water, and then, without drying, counter-stain with Loffler's methylene blue solution, allowing the stain to remain upon the preparation for about 30 seconds. Wash with water and dry in the usual manner by gentle heat.

Hanging Drop Cultures

The chief purposes served by the examination of hanging drop cultures are motility and spore formation.   In order to make the preparation, a drop of broth culture is placed upon a cover slip, which is then inverted over the concave depression in a specially prepared slide, the outer edge of the depression having been smeared with a ring of Vaseline.

This can be easily accomplished by means of a match stick. The drop should then be examined under the microscope by first focussing the margin of the drop with the low-power lens, and then finally with the 1/12 oil immersion objective. The bacteria—which of course are colourless, not having been stained—will be observed, although some little practice may be needed before they can be readily picked out. Care must be taken not to mistake movement due to currents in the liquid for the motility of the bacteria.

Summary

If a can be found to contain living bacteria, both aerobic and anaerobic cultures should be made in nutrient broth, or other suitable medium, and then agar and gelatine plates prepared by the methods already described. The colonies must be " fished " from the plate and examined microscopically, and where differences are apparent the organisms are grown in pure culture.

Caution must be exercised when examining the " fished " films, and if any points of dissimilarity are noted between two or more colonies, each should be grown in pure culture.

Having obtained the pure cultures, study their behaviour in various media--agar stab, gelatine stab, milk medium, etc.—and thus if possible arrive at some definite clue as to their class. Also examine for spore formation, flagella, and capsules by special staining. It should then be possible to decide upon the actual organism present, but it must be remembered that quite often one or more of the morphological characteristics of the organism become changed on account of the environment in which growth has taken place.

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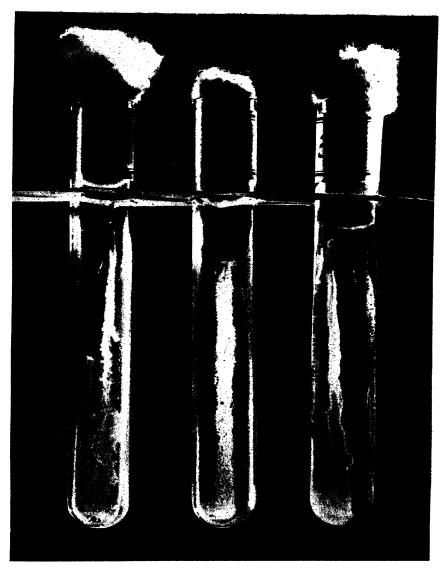
FIG. 50

AGAR SLANTS OF SOME OF THE BETTER KNOWN TYPICAL ORGANISMS. FROM
THE LEFT THEY ARE B. SUBTILIS (THE HAY BACILLUS), B. MESENTERICUS
, VULGATUS, AND STAPHYLOCOCCUS PYOGENES AUREUS

Courtesy of "Food"

[*Facing page* 184
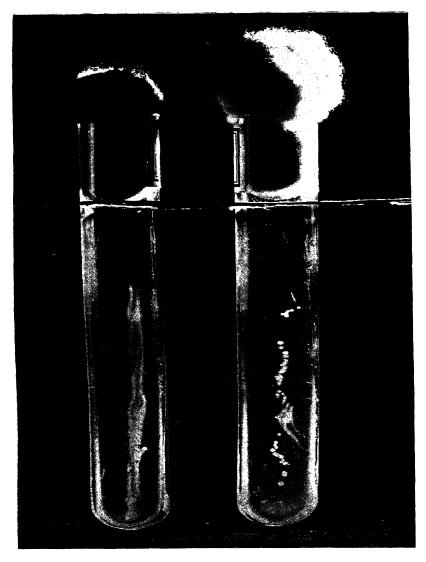
Fig. 51

AGAR SLANTS OF, LEFT, B. ENTERIDITIS (GARTNER) AND
RIGHT, OF ISOLATED COLONIES OF STAPHYLOCOCCUS
PYOGENES AUREUS. THE EXAMPLES ABOVE AND THOSE
IN FIG. 50 WERE ISOLATED FROM SAMPLES OF CONTAMIN-
ATED MEAT BY ONE OF THE AUTHORS

Courtesy of " Food "

CHAPTER XII

CULTURAL NOTES OF THE PRINCIPAL FOOD SPOILING ORGANISMS

IN Chapter IX we have described the method to be adopted for "fishing" colonies of organisms from the plate culture, so that their behaviour in pure culture can be studied and identification established, by which means the source of infection can often be traced. Sometimes it happens that only one kind of bacterium will be found—that is to say, that all the "fished" colonies will behave in the same manner under subsequent treatment, but more often the flora will be found to be a mixed one.

The variety of bacteria now known to cause spoilage in canned foods is so great that the problem of tracking down infection to any particular organism is extremely difficult. However, if one is familiar with the types usually associated with a particular class of product, the work becomes to some extent simplified. We therefore propose to discuss, under the various headings into which canning may roughly be divided, the organisms most commonly found to be the cause of spoilage in that kind of food. At the same time, it must be clearly understood that bacteria described as commonly occurring in one particular variety or group of foods are not to be considered as peculiar to that group, for they may be found in foods of quite a distinct nature. *B. subtilis* has often been isolated from such dissimilar products as canned fish and canned peas.

Vegetable Spoiling Organisms

In dealing with vegetables, it has been found that the American slogan " an hour from the field to the can," although not always possible of attainment, should nevertheless be aimed at, for food of this nature is very prone to " sweat " and develop acidity, thanks to the activities of organisms of the lactic acid group, particularly *Bacillus lacticus acidi*, which possesses a fermenting action upon sugar and starch with the production of lactic acid. If the material is not handled quickly after gathering, this sourness may develop before canning can be undertaken, and will result in an unpleasantly flavoured product, a muddy liquor, and an attack upon the tinplate. Fig. 52 is a microphotograph of a culture of *B. lacticus acidi* isolated from an imperfectly processed can of peas.

B. Lacticus Acidi

The characteristics of *B. lacticus acidi* are as follows :

Habitat. Found in sour milk and in fermenting vegetable matter.
Form. Very short rods.
Motility. It has no real motion except a Brownian movement.
Sporulation. Does not spore.
Staining. Stains readily with aniline dyes, such as carbol fuchsin, and is positive to Gram's stain.
Growth. Rapid and abundant.
Gelatine Plates. The deep colonies are oval or round, yellowish in colour, finely granular, with sharp borders. The surface colonies spread and form thin plates, with irregular edges. The outer zone of the colony is almost transparent at first, showing markings not unlike the veins in leaves.[1]
Stab Culture. The surface growth is considerable, and spreads rapidly as a thin white covering. Growth along the puncture is slight.
Streak Culture. On agar, a dirty white moist spreading growth is formed. On potato a brownish-yellow slimy growth is produced.
Milk. The lactose is converted into lactic acid and carbon dioxide. The casein will be thrown out of emulsion, and will form a clot. A considerable quantity of gas is produced.
Oxygen Requirements. It is a facultative anærobe.
Optimum Temperature of Growth. 28° to 30° C., but it will grow at temperatures between 7° and 45° C.
Gelatine is not liquified.
Pathogenesis. It is non-pathogenic. Its growth ceases when more than 0·75 per cent. lactic acid has been produced.
NOTE. There are several varieties of this organism.

Bacillus Butyricus

This organism, shown in Fig. 53, which is widely distributed, probably finds its way on to the peas owing to soil contamination.
Habitat. Cultivated soil, manure, grain, and milk, etc.
Form. Long narrow rods with rounded ends, frequently forms chains.
Motility. Actively motile.
Sporulation. Forms median spores, oval in shape.
Staining. Stains readily with aniline dyes. Gram-positive.
Growth. Very rapid.
Gelatine Plates. The deep colonies form masses of a yellowish colour ; the surface colonies rapidly produce liquefaction, and then form granular patches.
Stab Culture. Liquefies along the line of inoculation, and forms a thin greyish-white scum upon the surface ; the liquid gelatine soon becomes clear, the growth settling to the bottom of the tube.
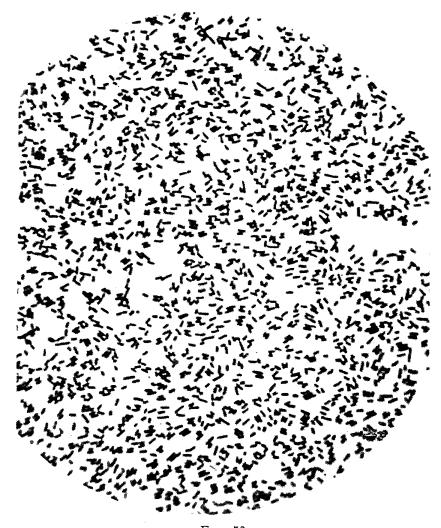
FIG. 52

CULTURE OF B. LACTICUS ACIDI ISOLATED FROM AN IMPERFECTLY
PROCESSED CAN OF PEAS. × 1120

Courtesy of "Food"

FIG. 53

CULTURE OF B. BUTYRICUS FROM FRESHLY GATHERED PEAS.   × 1120

Courtesy of "Food"

FIG. 54

CULTURE OF B. SUBTILIS, SHOWING SPORES, ISOLATED FROM A CAN
OF UNSOUND MEAT. × 1120

Courtesy of "Food"

FIG. 55

CULTURE OF B. MYCOIDES FROM CANNED SPINACH. × 1120

Courtesy of " Food "

Streak Culture on Agar.   Forms a greyish sticky growth.

On Potato.   A brownish transparent covering is formed.

Milk.   The casein is slowly coagulated, the appearance being similar to that produced by rennet.   After about a week to ten days, the casein is peptonised, with the formation of protein degradation products, such as tyrosin, and eventually ammonia.   It forms butyric acid from the lactates present in the milk, and this combines with the ammonia produced from protein decomposition to form ammonium butyrate.

Oxygen Requirements.   Facultative anærobe.

Temperature.   Grows at ordinary temperatures, but prefers 35° C.

Pathogenesis.   It is entirely non-pathogenic.

It should be noted that other organisms are capable of producing butyric acid by protein decomposition, *e.g., B. subtilis.*

Bacillus Subtilis (Hay Bacillus)

This organism, on account of its wide occurrence, and the high thermal death-point of its spores, is one of the most troublesome with which the canner has to contend.   Although its chief characteristics are described here in connection with the canning of vegetables, it should be noted that it is a source of infection likely to be found in all kinds of food, and is as liable to cause trouble in the meat canning factory as in one devoted to the handling of vegetables.

This organism is one of the most frequent causes of spoilage in canned meats.   It commonly occurs in hay, water and air, and is very abundant. It is a large organism, about 2μ to 3μ long by 1μ broad, and in its appearance is not unlike *B. Anthrax,* except that it is rather broader.   It is illustrated in Fig. 54.   It has rounded ends and grows in long threads ; it is very motile, possessing as it does long flagella.   It forms spores, which are ovoid in shape, and germinate at right-angles to the long diameter. The bacillus is Gram-positive.   It rapidly liquefies gelatine, and in a stab culture a funnel-shaped depression forms.   On agar, a white opaque expansion quickly forms, shown in Fig. 54, which is a 24-hour old growth of the organism at 37° C.   Its growth on potato is creamish-white, dull in appearance and spreading over the whole surface of the potato. Its frequent occurrence in unsound canned food, such as fish and meat, is to be attributed to the two facts that it is very widespread and thus likely to cause infection, and that its spores are extremely resistant to heat ;   they will withstand 100° C. for 6 hours.

Some workers describe the organism as strictly ærobic, but the fact that it is so frequently isolated from canned foods, which are normally of low uncombined oxygen content, indicates that it can exist and vegetate under conditions which cannot be regarded as particularly suitable to an

ærobic organism. It is therefore incorrect to describe all strains of *B. subtilis* as strictly ærobic.

Habitat.   In hay, air, water, fæces, etc.

Form.   Large and rather thick rods, with rounded ends, grows in long threads.

Motility.   It is extremely motile, with long flagella, sometimes 12 in number. Its motion is somewhat snake-like.

Sporulation.   It forms ovoid spores which germinate at right-angles to the long diameter of the organism. These spores are particularly resistant to heat and will withstand 115° C. dry heat for a period of 90 minutes.

Staining.   Stains very readily, and is also Gram-positive.

Growth.   One of the most rapid known. Duckwell[1] states that cell division has been noted to take place in 20 minutes at blood heat.

Gelatine Plates.   The surface colonies very readily liquefy gelatine in an extended area, the centre colony, which appears as a yellowish irregular mass surrounded by a lighter coloured granular zone, has a characteristic border consisting of threads radially arranged, with the ends projecting outwards.

Stab Culture.   Funnel-shaped liquefaction takes place very rapidly along the whole of the line. Flocculent masses deposit at the bottom of the tube, and a dense scum forms upon the surface.

Streak Culture on Agar.   A white opaque moist expansion is formed, which becomes dry and furrowed. On potato, a moist yellowish cream-like scum is formed over the whole surface.

Oxygen Requirements.   The organism is generally considered to be ærobic, but nevertheless varieties grow with considerable gas formation in hermetically sealed cans. It may be noted here that there are several organisms which so very closely resemble *B. subtilis* in their cultural habits that they are generally grouped together as the " hay bacilli." Some of these are undoubtedly facultative anærobes ; it is therefore difficult to classify this organism in regard to its oxygen requirements.

Temperature.   Grows readily at ordinary temperature, but its optimum is about 33° to 35° C.

Pathogenesis.   It is non-pathogenic.

Bacillus Mycoides

Habitat.   Very widely in the soil, and may be regarded as a typical soil organism. Is frequently found in water.

Form.   Large rods with slightly rounded ends, thicker than *B. subtilis*. Sometimes produces threads.

Motility.   Very slow movement.

Sporulation.   Forms small median spores.

Staining.   Stains readily and is Gram-positive.

Gelatine Plates.   Gelatine is slowly liquefied, the colonies appear to grow somewhat like the branches of a tree.

Stab Culture.   The growth develops along the line of inoculation, with thread-like growths penetrating into the surrounding medium. The appearance is quite characteristic, for the growth is much more rapid on the surface, so that its appearance is not unlike an inverted tree.   Eventually complete liquefaction of the gelatine takes place.

Streak Culture.   On agar a dirty white growth is formed, and shows the same thread-like growth as the stab culture in gelatine.   The growth on potato is similar.

Oxygen Requirements.   It is an ærobe.

Temperature.   Grows best at ordinary room temperature, but will also develop at blood heat.

Pathogenesis.   It is non-pathogenic.

Milk.   This is slowly and incompletely coagulated with little or no development of acidity.   Later the coagulum is digested.   The organism does not ferment lactose.

Fig. 55 is of a culture of *B. mycoides* obtained from canned spinach.

Bacillus Botulinus

On account of the numerous outbreaks of food poisoning, known as botulism, which occurred some few years ago in America, much study has been devoted to this organism, particularly in the United States.

Habitat.   Soils of all kinds.

Form.   A large bacillus, rounded ends, tendency to form chains.

Motility.   Slightly motile, flagellated.

Sporulation.   Forms terminal spores, very resistant to heat.   Meyer[3] gives the following data :

Spores are killed by moist heat in 4 minutes at 120° C.

,,	,,	,,	10	,,	115°
,,	,,	,,	33	,,	110°
,,	,,	,,	100	,,	105°
,,	,,	,,	330	,,	100°

Staining.   Stains with aniline dyes and is Gram-positive.

Growth.   Rapid.

Gelatine Cultures.   Produces a white line with side growths ; some gas is produced with liquefaction.

Milk.   Does not coagulate milk.

Glucose Media.   Produces gas with little or no acidity.

Oxygen Requirements.   It is strictly anærobic.   It should be noted that all its cultural growths must be studied and incubated under anærobic conditions.

Temperature. Will grow at ordinary temperature, but optimum is 22° C., growth almost ceases at 37° C. The presence of even traces of acidity will inhibit its growth.

Pathogenesis. It is extremely pathogenic on account of the toxin it produces, and 90 per cent. of the cases of infection prove fatal. The toxin is stated to be extracellular, and the intoxication is due to its formation in the food before ingestion. The organism is not very salt-tolerant, so that immersion of the vegetables in a 6·0 per cent. solution of salt inhibits the growth of the bacillus. For particulars of the symptoms caused by the toxin, works upon pathogenic bacteria should be consulted.

Organisms Producing " Flat-Sour " Spoilage

Such spoilage of peas is rare in this country, but McMaster[33] has traced such infection to the blancher, and determined the characteristics of a group of facultative thermophiles. These are as follows :

Form. The organisms occur as motile rods, singly and in pairs only occasionally in short chains. Spores are abundant, invariably swelling the rods. In size they are rather more than one micron in diameter and from 2·5 to 4 microns in length. All organisms are Gram-positive. Growth at 55° C. and 37° C.

Agar Colonies. Medium size, convex, edge entire, homogeneous, white. Older colonies tend to show a narrow outer ring of translucent growth.

Agar Slants. At 37° C. all strains showed beaded growth, but at 55° C. the type of growth was flat, filiform, moderate, glistening, rugose, opalescent, butyrous, white.

Gelatine Colonies. Unobtainable at 55° C. No growth at 20° C.

Gelatine Stab. Inoculated tubes incubated at 55° C. for seven days, and afterwards cooled to 20° C. Six out of the twenty-seven strains showed complete liquefaction. The remainder were negative.

Nutrient Broth. Very slight turbidity, no sediment, no pellicle formation.

Litmus Milk. Some growth occurs, but with the exception of four strains there is no change in reaction, no gas and no peptonisation. These four strains showed slight acid production and curdling.

Tryptophane Broth. Very slight turbidity, indol not formed.

Nitrate Broth. Nitrates not reduced.

Starch Agar. Hydrolysis negative.

Fermentation Reactions. All strains fermented dextrose with production of acid but no gas ; four fermented lactose, while sucrose was fermented by nineteen : eight strains failed to ferment either lactose or sucrose.

Temperature Relations. Optimum for growth 55° C., slight to moderate growth at 37° C., no growth at 20° C. Spores germinate at 37° C. and 55° C.

Oxygen Requirements. Facultatively anærobic.

Heat Resistance. The strains survived over a range of 4 to 14 minutes and were killed in 6 to 16 minutes at 115° C.

B. Mesentericus

The group of organisms usually described as Mesentericus Group and represented by *B. Vulgatus, B. Mesentericus, Mesentericus niger* and *Mesentericus flavus* (Ford)[5] are not so frequently found in unsound meat as in canned fish and vegetables, their chief habitat being water and the surface of vegetables. They are short, motile, sporulating organisms, usually measuring about $0·5\mu$. They readily liquefy gelatine, and produce a somewhat roughish granular growth on agar. They readily stain by Gram's method. The growth on potato is to some extent dependent upon the particular strain, *vulgatus* produces a dirty white colony, whilst *niger* is almost black in its appearance. The spores are not so resistant to heat as those of *B. subtilis,* and one hour at 110° C. is usually sufficient to kill them, although on occasion a more resistant strain may be met.

It is not possible to fix with any degree of certainty the thermal death-point of the vegetative forms and spores of many organisms. The figures have been found to vary over quite a wide range depending upon the age and concentration, the p_H value of the medium, the nature of the medium, etc., so that it does not necessarily follow that the organism, isolated and grown upon special medium, will necessarily follow the same cycle of life, as it will do inside a can of food where the conditions are perhaps widely different from those existing in a tube of medium. This fact makes it possible to explain the presence of spoilage organisms in the interior of a can which has been subjected to a treatment apparently certain to bring about sterility.

Bacillus Mesentericus Vulgatus

Habitat. Widely distributed in soil (particularly cultivated soil), on the surface of potatoes ; also found in milk, water, etc.

Form. Small thick rods, with rounded ends ; grows in pairs.

Motility. Actively motile ; possesses many flagella.

Sporulation. Large round-shaped spores ; very resistant to heat.

Staining. Very readily with aniline dyes ; Gram-positive.

Growth. Rapid, similar to *B. subtilis.*

Gelatine Plates. Dirty white, slightly granular in appearance, rapid and extensive liquefaction.

Stab Culture.   Growth along the complete length of the line of inocula-
tion, with rapid liquefaction.
Streak Culture on Agar.   Dirty white growth is formed.   On potato
a thick growth, usually red or dirty brown in colour.
Milk.   Coagulated and acid produced.
Oxygen Requirements.   Ærobic.
Temperature.   Grows readily at ordinary temperatures, also at 37° C.
Pathogenesis.   The organism is not pathogenic.

This organism is also known as the potato bacillus, and appears to
exist in more than one variety, some of these varieties forming a red,
and others white or brown growth on potato.
Fig. 56 shows a culture of *B. mesentericus vulgatus*.

Bacillus Prodigiosus

Habitat.   Soil, vegetables, foods, bread and milk.
Form.   A small coccobacillus, occurring singly, or sometimes in
chains of five or six.
Motility.   Fairly active, with usually four flagella.
Sporulation.   Does not form spores.
Staining.   Stains with aniline dyes, but is Gram-negative.
Growth.   Fairly rapid.
Gelatine Plates.   Slightly granular, rather thin, dirty white at first,
afterwards becoming red and causing liquefaction.
Gelatine Stab.   Produces liquefaction throughout the stab, with sedi-
ment of a reddish colour.
Streak on Agar.   White growth turning red in about three days, and
producing a lustre, almost metallic in appearance.
Oxygen Requirements.   Facultative ærobe.
Temperature.   Optimum 20° to 25° C., little or no growth at 37° C.;
produces red colour best at the lower temperature.
Pathogenesis.   Has been stated to produce infantile diarrhœa when
milk infected with the organism has been fed to infants.
Milk.   Produces an acid reaction and a soft curd, with a red surface
growth.

The peculiarity of this organism is the production of a red pigment.
A culture from canned runner beans is illustrated in Fig. 57.

Bacillus Viscosus

Habitat.   Water, milk.
Form.   Short rods with rounded ends, usually occurring singly, very
seldom in pairs.
Motility.   Movement somewhat sluggish ; peritrichous flagella.
Sporulation.   Does not form spores.

FIG. 56

CULTURE OF B. MESENTERICUS VULGATUS (" POTATO BACILLUS ").
× 1120

Courtesy of " Food "

FIG. 57
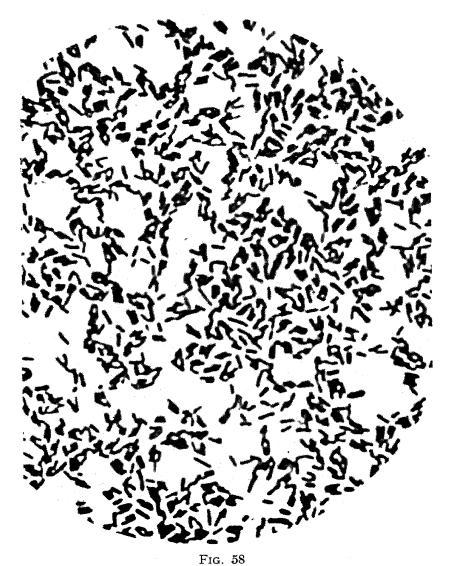
CULTURE OF B. PRODIGIOSUS FROM A CAN OF IMPORTED RUNNER
BEANS.   × 2000

Courtesy of " Food "

FIG. 58

CULTURE OF B. VISCOSUS, ISOLATED FROM A CAN OF ASPARAGUS
IMPORTED FROM AMERICA.   × 2000

Courtesy of " Food "
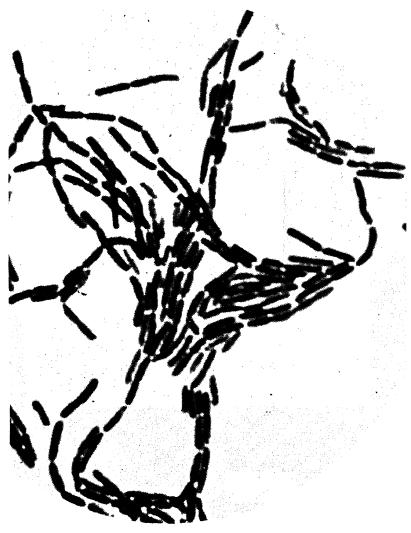
FIG. 59

CULTURE OF B. RAMOSUS, ISOLATED FROM CANNED TOMATOES.
× 2000

Courtesy of " Food "

Staining. Stains with aniline dyes. Gram-negative.
Growth. Fairly rapid.
Gelatine Plates. Dirty white in colour with fringed edge.
Gelatine Stab. Funnel-shaped, with a greenish-white pellicle. No liquefaction.
Streak Culture on Agar. Thin, and greenish-white.
Potato. Moist and slimy, dirty brown in colour.
Oxygen Requirements. Facultative ærobe.
Temperature. Grows best at 20° to 22° C.
Pathogenesis. Non-pathogenic.

This organism, illustrated in Fig. 58, is one of those causing sliminess in milk, which it does not coagulate.

Bacillus Ramosus (Bacillus Cereus)

Morphologically very similar to *B. mycoides.*

Habitat. Soil and water.
Form. Rods, usually rather large with rounded ends, occurring singly and also in chains.
Motility. Very sluggish ; possesses flagella.
Sporulation. Forms central spores.
Staining. Readily with aniline dyes. Gram-positive.
Gelatine Plates. Filamentous, greyish-white in colour; slow liquefaction. Edges of colonies very irregular.
Gelatine Stab. Liquefaction takes place slowly down the whole line of inoculation ; stab appears craterlike.
Streak Culture on Agar. Thick white to yellowish-white growth.
Milk. Sometimes slight coagulation not very marked, with no development of acidity.
Oxygen Requirements. Facultative ærobe.
Temperature. Will grow at ordinary temperatures, but prefers 28° to 30° C.
Pathogenesis. Non-pathogenic.
The organism is shown in Fig. 59.

Mycoderma Aceti

Although this organism is usually associated with vinegar and beer, it has been isolated from canned tomatoes. These had apparently not been subjected to a satisfactory processing, because the thermal death-point of the organism is quite low—60° C.—and it does not sporulate.

Habitat. Beer wort, vinegar, and fermenting fruits and vegetables.
Form. Short dumbell-like rods, occurring in chains and sometimes singly.
Motility. Not motile.

Sporulation. Does not spore, but produces involution forms, which might be mistaken for spores.

Staining. Stains yellow with iodine, and also takes aniline dyes.

Gelatine-beer Plates. Forms large colonies, somewhat shiny in appearance ; on fluid media it produces a small pellicle of a yellowish-brown colour.

Oxygen Requirements. Strictly ærobic.

Temperature. Optimum temperature is about 27° C., but it will grow well between 24° and 30°.

Pathogenesis. It is non-pathogenic.

Illustrated in Fig. 60.

The organisms which are mostly likely to be met with by the vegetable and fruit canner are those the morphological characteristics of which have been described, *B. lacticus acidi, B. butyricus, B. subtilis, B. mycoides, B. botulinus, B. mesentericus vulgatus, B. viscosus, B. ramosus, B. prodigiosus, mycoderma aceti.* It cannot, however, be too strongly emphasised that any attempt to make a complete list of all those which might be found would be a difficult if not impossible task. Bacteria as a whole are very prone to adapt themselves to any media with which they come into contact. If trouble arises in regard to spoilage of fruit or vegetables, and the organism causing it does not tally with those described, then further efforts must be made to identify it. It may quite well be one of those whose habitat is usually meat or sewage or milk.

Meat-Spoiling Organisms

Before giving detailed descriptions of some of the more common organisms which the manufacturer of preserved meats is likely to find in the materials he has to handle, it is necessary to point out that although the usual thermal death-point of a particular organism may be in the region of 60° C., it can be found in an active state in a can of food which has been subjected to temperatures much above 60°. The reason is not at present understood, and is the subject of special investigation in one of the authors' laboratories. It would seem that under special conditions, the exact nature of which is not yet known, the medium in which the bacteria is growing exerts a protective action towards the protoplasm of the organism. Tanner[6] has apparently observed the same phenomenon, but is unable to offer an explanation. Meat appears to be particularly prone to provide this protective action, and the technologist engaged in the meat-canning industry must be prepared to find in his finished products organisms which should most certainly have been destroyed by the high processing temperature to which canned meat is usually subjected.

The following are organisms commonly found in meat products :
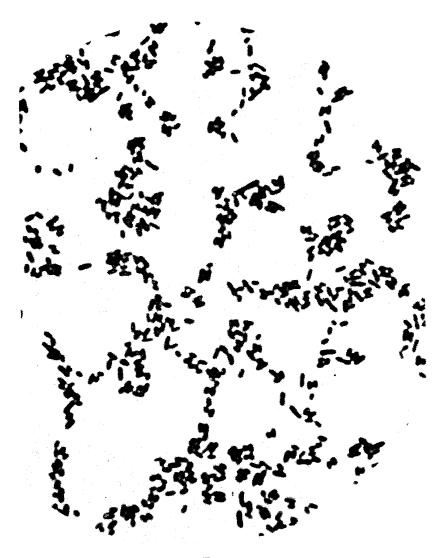
FIG. 60

CULTURE OF MYCODERMA ACETI. × 2000

Courtesy of "Food"

FIG. 61

CULTURE OF B. PROTEUS VULGARIS ISOLATED FROM A CANNED OX
TONGUE. × 2000

Courtesy of " Food "

Fig. 62

CULTURE OF B. PUTREFICUS ISOLATED FROM A CAN OF BEEF IMPORTED
FROM THE ARGENTINE. × 2000

Courtesy of " Food "

FIG. 63

CULTURE OF B. MEGATHERIUM ISOLATED FROM CANNED SPINACH.
× 2000

Courtesy of " Food "

Bacillus Proteus Vulgaris

Habitat.   Very widely distributed.   Commonly found on putrefying protein matter, in slaughterhouses, and sometimes in water.

Form.   Rods of varying length, sometimes found bent ; grows in pairs, singly and often in long chains.

Motility.   Very motile, possessing many flagella.

Sporulation.   Does not form spores.

Staining.   Readily with aniline dyes, but is Gram-negative.

Growth.   Grows very quickly.

Gelatine Plates.   Very irregular in form, and causes rapid liquefaction. Under optimum conditions the colonies will spread over the whole surface of the plate in 48 hours.

Gelatine Stab.   Liquefaction takes place along the whole line of the stab in a short period, and in about 3 days the whole of the medium will be liquefied.

Surface Colonies on Agar.   Thin dirty grey in appearance, rapidly spreading over the whole surface.

Broth.   Very turbid ; sometimes a pellicle forms.

Oxygen Requirements.   Facultative ærobe, but will sometimes grow under anærobic conditions.

Temperature.   Will grow well at room temperature ; optimum seems to lie between 20° and 37° C., a very wide range.

Pathogenesis.   Doubtful ; said to be toxicogenic to rabbits in large doses.

Illustration, in Fig. 61, is of culture isolated from a canned ox-tongue.

This is one of a large group of organisms known as the Proteus Group, the majority of which reduce nitrate to nitrite.   It may therefore play a part in the cure of meat.   Nearly all the members of the group produce acid and gas in glucose and lactose media.

Bacillus Putreficus

Habitat.   Intestinal canal.

Form.   Long rods, occurring nearly always in chains.

Motility.   Possesses many flagella.

Sporulation.   Produces large terminal spores, which are highly heat-resistant when young.

Staining.   Stains with aniline dyes and is Gram-positive.

Growth.   Not very rapid.

Gelatine Plates.   Small, usually circular, with slight liquefaction.

Gelatine Stab.   Slow growth, and some liquefaction after about 7 days.

Broth.   Becomes turbid, with particularly bad odour.

Sugar Medium.   No action.

Oxygen Requirements.   Anærobic.

Temperature. Grows best at blood heat—37° C.

Pathogenesis. This organism is not pathogenic.

This bacillus, being an anærobe, is an inhabitant of the intestinal track of animals. It produces highly heat-resistant spores and can be the source of much trouble to meat-canners. Trouble is likely to arise if the strictest cleanliness is not observed in the slaughterhouse, for if the contents of the intestine are allowed to come into contact with the flesh of the slaughtered animal, contamination with this organism is almost bound to occur.

The illustration, Fig. 62, is of a culture isolated from a can of imported beef from the Argentine.

Bacillus Megatherium

This organism, a frequent cause of spoilage, is widely distributed, and is found on most decomposing vegetables and animal matter.

Origin. Probably originates in the soil, but is found also in water and on growing vegetable matter, manure, and decomposing protein substances.

Form. Large rods, somewhat irregular in shape, particularly in old cultures ; usually three or four times as long as broad. Occurs singly and also in pairs ; seldom in chain formation.

Motility. Possesses four to ten flagella, and has a very slow movement ; can almost be said to creep.

Sporulation. Forms central spores, with varying resistance to heat. As with many other sporulating organisms, the thermal death-point appears to vary with the age of the spore, the young spores generally being more resistant.

Staining. Stains with aniline dyes, in some instances rather irregularly —stated by Duckwell[1] to be due to the presence of granular protoplasm in the cells. The organism is Gram-positive.

Growth. Rapid.

Gelatine Plates. Greyish-white to pale yellow, somewhat raised.

Stab Culture in Gelatine. Rapid growth along the line of inoculation, attended by liquefaction with some branching threads, passing into the solid medium.

Streak Culture on Agar. A dirty white or grey growth, somewhat slimy in appearance, later turning brownish-yellow.

Nutrient Broth. This organism does not grow well in any liquid media, but some growth is apparent.

Milk. Does not coagulate milk.

Oxygen Requirements. Generally ærobic, but sometimes found as a facultative anærobe.

Temperature.   Opinions differ as to the optimum, but it will be found to make rapid growth at blood heat, and some growth even at 50° C.

Pathogenesis.   The organism is non-pathogenic.

The accompanying microphotograph, Fig. 63, is of a culture isolated from a can of spinach.

Staphylococcus Pyogenes Aureus

This is strictly a pathogenic organism, forming local abscesses and, in the blood circulatory stream, septicæmia.   It is extremely well known and its usual habitat is most probably the surface of the body, although it is frequently found in dust, and sometimes in water.   It should not normally find its way into canned foods, for being a non-sporing organism it is readily destroyed by heat, so that its occurrence is unlikely, except in those cases where a low processing temperature is employed, such as that used in the preparation of some varieties of condensed milk. As its name indicates, it grows in bunch-like clusters, the individual organisms being spherical.   It may however under unfavourable conditions occur as a diplococcus.   It is a facultative anærobe, and grows readily at blood heat or room temperature.   On agar slant medium it grows as a thick streak which quickly develops a yellowish tint.   Strains are known, however, which remain white in appearance.   The separate colonies on agar appear to protrude and possess a shiny surface, which sometimes appears to be slightly fluorescent.   The thermal death-point of this organism is generally accepted as being 60° C. to 65° C., but Jordan[7] cites a case where the organism resisted a temperature of 100° C. for 30 minutes.   There is little doubt that here again the resistance to heat depends upon a number of circumstances, but it is doubtful if any strain could withstand boiling temperature, even momentarily.   There are other types of staphylococci, some which are pathogenic like *aureus* and some which are apparently quite harmless, the function of which it is difficult to understand.   In a properly conducted food factory undue trouble should not arise through the presence of organisms of this type, but they may lead to difficulties when the food is allowed to become stale before handling, because there is little doubt that some strains of staphylococci are capable of producing heat-resistant toxins which cause gastro-intestinal disturbance of an acute nature.

Habitat.   Skin and mucous membrane ; it is the cause of boils, abscesses, etc.

Form.   Spheres, varying in size ; usually occur in bunches, but sometimes singly or in groups of two or three.

Motility.   No movement.

Sporulation.   Does not form spores.

Staining.   Stains readily with aniline dyes, and is Gram-positive.

Growth.   Rapid.

Gelatine Colonies. Yellow to orange growth, with liquefaction. As the organism does not grow rapidly at room temperature, the formation of the colonies is somewhat slow.

Gelatine Stab. The gelatine begins to liquefy as soon as growth begins, and liquefaction occurs along the whole stab. At the same time a yellow to orange sediment is formed.

Agar Streak. Very rapid growth; culture appears yellow in colour.

Nutrient Broth. Growth is rapid, and yellow to orange in colour; some sediment is produced, and the broth gradually becomes clear (Bergey).[8]

Milk. Produces acidity in milk, and consequently coagulation occurs.

Oxygen Requirements. Facultative ærobe.

Temperature. Optimum is 37° C., but will grow slowly at room temperature.

Pathogenesis. The organism produces local abscesses, and if injected into the blood stream, septicæmia. It is also now recognised that under some conditions it forms a toxin which, in the stomach, produces gastric disturbance with acute sickness and diarrhœa.

The thermal death-point of this organism is usually stated to be 58° to 60° C., but it shows a very much higher resistance to heat under conditions which are not well understood. The presence of this organism in lightly processed canned foods is by no means unknown, and it may produce a toxin which, according to Jordan,[7] will withstand a temperature of 100° C. for 30 minutes.

The illustration, Fig. 64, shows a microphotograph of a culture isolated from a can of prawns.

B. Welchii

Although not commonly regarded as a food spoiling organism, McClung and Wheaton[35] report cases of " roast beef " so contaminated as to cause hard hydrogen swells during processing. Upon investigation they found the raw meat to have been infected with *B. Welchii*. The spores apparently were not killed in the pre-cook, but propagated sufficiently in the warm meat to produce sufficient gas to swell the cans. Head space gas analysis showed the gas to consist of 20 to 22 per cent. CO_2 and 70 to 75 per cent. H_2. The meat appeared normal and there was no odour of putrefaction.

Habitat. General, fæces, human intestine.

Form. Plump, straight rod, slightly rounded ends ; width, 1 micron ; length 4 to 8 microns.

Motility. Non-motile.

Sporulation. Spores not formed in all media, favoured by alkaline media, high in protein and low in carbohydrates, oval.

FIG. 64

CULTURE OF STAPHYLOCOCCUS PYOGENES AUREUS ISOLATED FROM
A CAN OF PRAWNS. × 2000

Courtesy of " Food "

Staining. Gram-positive in young cultures, granular and even Gram-negative in old cultures.

Growth. Rapid in meat media with evolution of acid and violent gassing.

Gelatine Stab. Liquefied and blackened.

Agar Colonies. Circular, moist, slightly raised, opaque centre.

Oxygen Requirements. Anærobe.

Indol. Not formed.

Nitrates. Not reduced.

Temperature. Optimum growth at 37° C., will grow at as low as 10° C. and as high as 50° C.

Pathogenesis. Produces active toxin of two fractions, one being hæmolytic and the other cytolytic. Can be tested by killing power on guinea pigs. Not effective when administered orally, hence does not constitute a health hazard.

Milk. Rapidly produces an acid curd, which is " torn " by gas formation, giving the typical " stormy fermentation."

Staphylococcus Albus

The main differences in the cultural details of this organism and *Staphyl. p. aureus* are that in all cases the growths on various media are white, and that this organism does not reduce nitrates to nitrites, a change rapidly brought about by *Staphyl. p. aureus*. It is pathogenic, and occurs in wounds, boils, etc. It does not, however, appear to produce a gastric toxin. Andrews and Gordon[10] regard the *albus* as of the same species as the *aureus*, but there is some doubt on this point.

Bacillus Thermophilus

Habitat. Soil and dung.

Form. Curved rods, usually occurring in pairs, but sometimes singly.

Motility. Non-motile.

Sporulation. Forms central spores.

Staining. Stains with aniline dyes and is Gram-positive.

Growth. Varies, sometimes rapid, more usually rather slow.

Agar Plates. Dirty greenish-white, and somewhat granular in appearance.

Nutrient Broth. Turns broth alkaline.

Oxygen Requirements. Facultative anærobe.

Optimum Temperature. 60° to 64° C., but will grow very slowly at lower temperatures.

Pathogenesis. The organism is non-pathogenic.

Infection of canned foods by this organism is rare but extremely troublesome to remove. On account of its thermophilic property, the scrubbing of utensils used in the handling of food with hot water is

insufficient. For this reason the use of sodium hypochlorite is recommended, accompanied by the steam sterilisation of trays, etc., where this is possible.

Milk Spoiling Organisms

Because of the method adopted in the preparation of condensed milk, it is seldom found to be sterile, but in the sweetened variety the high concentration of sugar has the necessary inhibiting effect upon microbial growth, so that spoilage is unlikely to occur. Several different types of organism are, however, known, and the bacteriology of all of them has not been thoroughly studied. Of the commoner types, the following may be briefly described :

Bacillus Coagulans

Origin. Condensed milk. (Isolated by Hammer, 1915.)[11]
Form. Rods varying much in size, occurring singly and in chains.
Motility. The organism is motile and flagellated.
Sporulation. Small central spores.
Staining. Will take aniline dyes and is Gram-positive.
Gelatine Colonies. Quite white ; does not liquefy.
Agar Streak. White at first, becoming greyish-white.
Nutrient Broth. Rapidly produces turbidity, and some sediment.
Milk. Acid produced and much coagulation.
Oxygen Requirements. Facultative ærobe.
Optimum Temperature. About 53° C. It may therefore be classified as a thermophilic organism.

Organism causing Bitterness in Canned Cream

This organism described by Macmaster[34] is stated to correspond closely to *B. cohærens* but is not identical with it.
The morphological characteristics are as follows :

Habitat. Canned cream.
Form. Rods occurring singly, in pairs or in chains.
Motility. The organism is motile and possesses peritrichous flagella.
Spore Formation. Abundant. Central to eccentric.
Staining. Gram-positive.
Agar Colonies. Freshly isolated colonies are amœboid in shape but on sub-cultivation tend to assume the circular form. They are smooth, raised, white to cream colour, glistening, homogeneous, viscid.

Agar Slant. Growth is smooth, raised, white to cream colour, glistening, homogeneous, viscid.

Gelatine Stab. Liquefaction slow, saccate to infundibuliform, a white pellicle forming in six days.

Nutrient Broth. Turbid with dense flocculent pellicle.

Litmus Milk. Alkaline, coagulation with subsequent peptonisation which is complete after 7 days, at 37° C. The indicator is reduced and a bitter taste develops after three days.

Tryptophane Broth. Indol is not formed.

Nitrate Broth. Nitrates are not reduced.

Starch Agar. Growth abundant, starch hydrolysed after two days.

Carbohydrate Broth. Acid but no gas in dextrose, sucrose and lactose.

Optimum Temperature. Not determined but grows well at 37° C.

Bacillus Amarus (Hammer 1919)

Habitat. Condensed milk.

Form. Short rods, occurring singly, in pairs, and also in chains.

Motility. The organism is motile and flagellated.

Sporulation. Forms central spores.

Staining. Takes aniline dyes, and is Gram-positive.

Gelatine Colonies. White, inclined to be shiny, with no liquefaction.

Agar Streak. White.

Nutrient Broth. Causes turbidity, and a sediment forms.

Milk. No coagulation ; slight acidity sometimes produced.

Oxygen Requirements. Facultative ærobe.

Optimum Temperature. Blood heat.

Spitzer and Epple[12] isolated from condensed milk an organism closely resembling *Lactobacillus panis*, the cultural details of which are as follows :

Lactobacillus Panis

Habitat. Isolated from sour dough and probably condensed milk.

Form. Rods, occurring singly, in pairs and in chains.

Motility. Non-motile.

Sporulation. Uncertain.

Staining. Will stain with aniline dyes, and is Gram-positive.

Agar Colonies. Greyish-white and flat.

Milk. Produces acid.

Oxygen Requirements. Facultative ærobe.

Optimum Temperature. Blood heat.

Although organisms of the *B. coli* group are invariably found in raw milk, they do not apparently survive the temperature to which the milk is subjected during concentration (54° to 60° C.). As a consequence, they

are seldom found in condensed milk. Their presence is evidence of faulty manufacture. The cultural details are as follows :

B. Coli Communis

Habitat. Intestinal canal of man and animals, whence it finds its way into milk and water.

Form. Short rods, occurring singly, in pairs, and in chains.

Motility. Is motile, with flagella.

Sporulation. Has not been observed.

Staining. Stains readily with aniline dyes, but is Gram-negative.

Growth. Rapid.

Gelatine Plates. Dirty white surface colonies, with irregular edges.

Gelatine Stab. Greyish-white spreading. No liquefaction.

Agar Streak. Similar in appearance to gelatine colonies, but slowly becomes dirty brown.

Milk. Peptonises, with slow coagulation.

Broth. Much turbidity with heavy sediment.

Oxygen Requirements. Facultative ærobe.

Optimum Temperature. 37° C.

Pathogenesis. Doubtful.

The organism possess the property of producing acid and gas in lactose and other sugar bouillon in the presence of bile salts (MacConkey's medium).

A typical culture is shown in Fig. 65.

Bacillus Icthyosmius

This organism was isolated from condensed milk, possessing a fishy odour (Hammer[13]).

Habitat. Condensed milk.

Form. Short rods, occurring singly.

Motility. The organism is motile, and therefore probably possesses flagella.

Aniline Dyes. Takes aniline dyes, and is Gram-negative.

Gelatine Stab. Rapid liquefaction occurs.

Agar Colonies. White, becoming dirty white with age.

Milk. Produces a fishy odour ; slight coagulation.

Oxygen Requirements. Facultative ærobe.

Optimum Temperature. 20° C.

Clostridium Sporogenes

A strain of this class with its exceptional power of heat resistance isolated from air-borne dust containing animal fur has been investigated by Baumgartner and Wallace.[36] They compared it with strains number
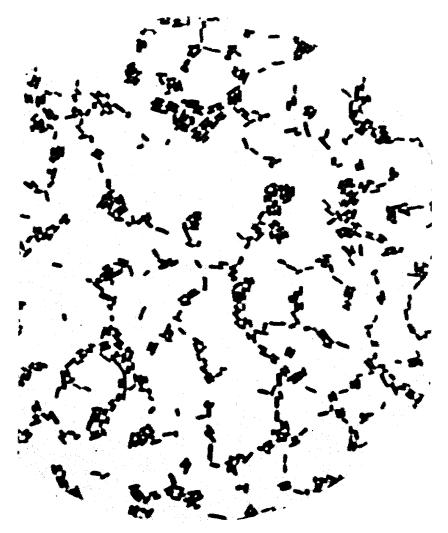
FIG. 65

CULTURE OF B. COLI COMMUNIS. × 2000. NOTE SHOULD BE TAKEN
OF THE FORMATION OF SHORT RODS OCCURRING SINGLY, IN PAIRS
AND IN CHAINS

Courtesy of " Food "

42 and Bellette obtained from the National Collection of Type Cultures and have called it Strain No. 14.

Morphology. In 24- and 48-hour cultures, the cells occur singly or in pairs and vary somewhat in size. The average dimensions are 5 by 0·6. The rods are rounded at the ends.

Spores. Spores occur freely on all ordinary media. They are large oval bodies, situated terminally or sub-terminally, but are occasionally found almost central. The rods are swollen at sporulation, and in old cultures the vegetative portion of the cell tends to disappear.

Motility. The cells exhibit a sluggish motility, while an occasional cell is actively motile. The disposition of the flagella is peritrichous.

Staining. The cells are uniformly stained by Gram's method.

Oxygen Requirements. The organism is an obligate anærobe.

Temperature. Optimum growth at 37° C. Growth occurs at 22° C. No growth at 56° C. in 14 days.

Agar Colonies. The colonies are round, convex, and smooth. Examined by direct light, the colonies appear finely granular, becoming translucent at the periphery, which is entire to undulate. The colony is readily emulsified in water.

Agar Streak. Beaded.

Cooked Meat Medium. In this medium there is at first a slight reddening of the meat, which is subsequently blackened and digested with the production of a large volume of gas and foetid odour. An analysis of the gas formed in a cooked meat culture gave the following result :

$$\begin{aligned} CO_2 &= 75\cdot5 \text{ per cent.} \\ H_2S &= 18\cdot8 \quad ,, \\ N_2 &= 5\cdot3 \quad ,, \\ H_2 &= nil \end{aligned}$$

Nutrient Broth. There is an even clouding of the medium with a greyish sediment which is somewhat viscid.

Milk. Within 24 hours the casein is precipitated, followed by rapid peptonisation. Gas is produced. There is a slight increase in p_H during digestion.

Solidified Egg Medium. The cube of solidified egg is completely liquefied in 4 days.

Gelatine. Rapid liquefaction (within 48 hours).

Indol Production. No evidence of indol production in 10-day cultures tested with Erlich's reagent.

Nitrate Reduction. No reduction of NO_3 in 10-day cultures tested with sulphanilic acid-naphthylamine reagents.

Fermentation Reactions. Acid and gas is produced in dextrose, maltose, and glycerol.

The organism appears to be quite capable of withstanding the heat treatment usually accorded to canned products such as soups, and since it is extremely proteolytic, infection with it is bound to result in loss, due to gaseous spoilage.

Food   Poisoning

With the exception of *B. botulinus*, consideration has been given to those organisms which are commonly associated with spoilage of canned foods, as distinct from pathogenic organisms, which may cause illness as a result of consuming the food.   Illness which is occasioned by the consumption of harmful food can be divided into two distinct classes : (1) endogenous food-poisoning, where the article of food may in itself be poisonous; (2) exogenous food-poisoning, caused by what are apparently wholesome articles of common diet.   It is with this latter class that the food industry is chiefly concerned.

Exogenous food-poisoning can be caused in a number of different ways. Outbreaks may be due to the contamination of the food with mineral or organic poisons.   These cases are infrequent, but nevertheless of sufficient importance to warrant the attention of those engaged in the preparation and handling of foods.   Savage and Bruce White[14] gave an instance of an outbreak in an institution in Surrey caused by the consumption of stewed apples prepared in a galvanised iron pan.   They also quote a case of belladonna poisoning brought about by the consumption of stuffed roast mutton ;   the sage used in the stuffing contained a proportion of belladonna leaves.

Some thirty years ago a " scare " was created by an outbreak of illness traced to the presence of arsenic in beer, arising from the use of glucose, in the preparation of which sulphuric acid containing a relatively large quantity of arsenic had been used.   There is the more recent case of antimony poisoning brought about by the preparation of " synthetic " lemonade in enamelled containers, the enamel of which was partially composed of antimony salts.

Food manufacturers must therefore take the necessary precautions to ensure that the materials they use are free from accidental contamination of this nature, and that during the course of handling they do not come into contact with any substances which could render them harmful. Due consideration has to be given to the nature of the materials being dealt with, and the kind of vessels used.   For example, the heating of acid fruits in copper or galvanised pots would be likely to lead to the absorption of the metal by the fruit.

Flesh Foods

Animals on occasion consume food which makes meat derived from them poisonous. According to Ostertag,[15] for vertebrates such food may be colchicum, equisetum, lupines, buckwheat (intermingled with fodder), sprouting potatoes, ricinus, mustard cake, etc. Shell-fish and poisonous tropical fish also appear to derive their poisonous nature in certain cases from their food (Letheby[16]). Flesh foods may also be made poisonous by the animal's accidentally eating definite mineral or organic poisons such as lead, phosphorus or arsenic, or by improper medications (by tartar emetic, mercury, strychnine, etc.). The animal itself may not be killed or even made sick by the consumption of such food (Allen[17]).

The substances somewhat loosely known as leucomaines are protein degradation products; they include choline, neurine, betaine, trimethylamine, cadaverine, etc. Some are harmless; others, such as neurine, are distinctly harmful. Under normal conditions they are rapidly eliminated from the animal system, and it is considered that the chief cause of abnormal quantities in the flesh is over-fatigue. For example, they may occur in hunted game, hard-driven cattle, or animals exhausted by violent struggling in traps (Gautier[18]). It should be added that cases of this type are exceedingly rare.

Bacterial Food-Poisoning

Bacterial food-poisoning is by far the most frequent cause of illness from the consumption of food, and may arise in several ways :

(1) The presence in the living animal of pathogenic bacteria which caused its illness prior to slaughter.

(2) The presence of pathogenic bacteria, in or on the food, which produced no illness in the animal itself.

(3) The presence of toxins produced in the food as the result of bacterial action ; in this event the organism may or may not be still living. This is the type of poisoning which was formerly attributed to the presence of substances called " ptomaines." During the decomposition of proteins, bodies somewhat similar to the vegetable alkaloids may be formed ; some of these, such as muscarine and tyrotoxicon, have very toxic properties. Sir William Willcox, in an address given to the Canned Food Section of the London Chamber of Commerce in 1922, said : " The idea that food poisoning is due to ptomaines is quite exploded. I have made a very large number of analyses in fatal cases of poisoning and suspected poisoning ; but although I searched most minutely for all signs of alkaloidal poisons, ptomaines, and so on, unless there was some genuine chemical poison there, my efforts to find these poisons failed. I used not to succeed in finding ptomaines in the viscera which were examined, though many of them were of an extremely advanced nature

as regards the decomposition which had occurred. So that we can dismiss these ptomaines as the cause of food poisoning."

Organisms in the Animal

The only organism definitely associated with outbreaks of poisoning caused by the presence of pathogenic bacteria in the living animal is *B. enteriditis (Gartner)*. This bacillus has been isolated from the flesh of pigs, cattle, horses and flesh. In many instances the meat had been derived from animals suffering from enteriditis. Its occurrence in this country is rare, but on the Continent outbreaks are less uncommon. It usually follows on cases of " emergency " slaughter of diseased or dying animals, a practice which is dangerous, the flesh from such animals being fit only for the manufacture of fertiliser. Regulations in the United Kingdom in regard to the handling of carcases from animals in this condition are very stringent.,

It is, however, by no means certain that *B. enteriditis (Gartner)* does not sometimes occur as a normal inhabitant of the intestine of many animals, and if there is careless handling of the viscera there is some possibility of flesh becoming infected with this and other intestinal organisms.

According to Mitchell,[19] there are cases on record wherein the bacteria associated with pyæmia and septicæmia, from animals infected with these diseases at the time of slaughter, caused sickness among consumers.

Contact between a piece of sound meat and a piece of infected meat will frequently cause the former to become infected.

B. enteriditis (Gartner) is readily destroyed by heat. A temperature of 60° C. maintained for 20 minutes is sufficient to bring about its death, but the toxin which it produces is much more resistant ; it will withstand 100° C. for at least 30 minutes.

Savage and Bruce White[14] mention only one case in which *B. enteriditis (Gartner)* was isolated—from a Cornish pasty.

Organisms In or On the Food

In cases of poisoning caused by the presence of pathogenic bacteria in or on the food—which however caused no illness in the animal itself—it should be understood that the organisms responsible for the sickness of the consumer are themselves present in the food, and will produce the toxin after consumption. It frequently happens that no sickness is apparent until a period of from 24 to 48 hours, or even longer, has elapsed after eating, during which time the toxin is being produced in the system.

The organisms which give rise to this type of poisoning belong to the *Salmonella* group. The cultural characteristics of the different members of this group are very similar, but extended serological tests have shown that there are several distinct types, named according to the
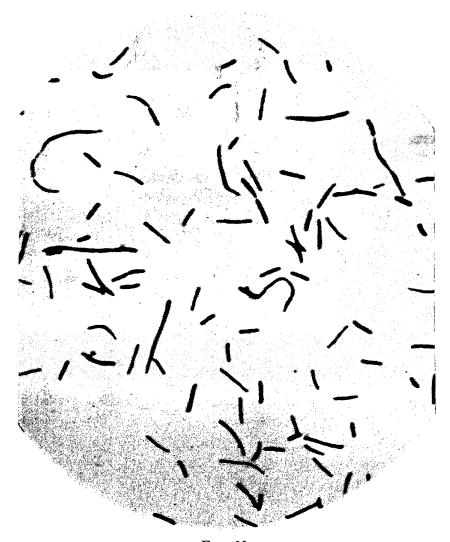
Fig. 66

A YOUNG CULTURE OF B. ENTERIDITIS (GARTNER). × 1700

Courtesy of " Food "

locality from which the infected food came (*Salmonella Newport, Salmonella Reading, Salmonella Derby*, etc.). The bacilli are readily destroyed by heat, so that their occurrence in a living condition on recently well-cooked meat is most improbable. The meat may become infected after cooking, by fly- or dust-borne contamination, and therefore the exposure of cooked meat to these risks is a possible manner in which it may become poisonous. Savage and Bruce White[14] mention twenty cases in which the harmful nature of the food was found to be due to living *Salmonella*; and these cover quite a wide range of foods, such as milk, cheese, canned apricots, roast pork and sausages. More recently, illness caused by the consumption of ice-cream has been traced to the presence in it of living *Salmonella* organisms.

The Nature of Toxins

By far the most important cause of food-poisoning is the consumption of food containing toxins produced by bacterial action—very often due to contamination of the food itself either in the shop or in the home.

Toxins are supposed to be protein in nature,[20] and in many instances resemble enzymes. They are probably not protein degradation products, but specific metabolic products of the bacterial cell. They may be retained in the cell as an integral part of it, in which event they are known as " endotoxins " or " intracellular toxins " ; or, after their formation in the cell, they may be excreted into the surrounding medium, these being called " extracellular toxins." It is probable that the *Salmonella* group of organisms produce endotoxins.

The toxins themselves being with difficulty destroyed by heat, food infection from this source is more likely to occur than from any other. Indeed, in many cases where poisoning has arisen as the result of the consumption of canned foods, the cause has been traced to the presence of undestroyed toxins, indicating that the processing or cooking of the food had not been conducted at a sufficiently high temperature to bring about the removal of the toxin itself, although the organism producing it has been destroyed. There is a great deal of uncertainty as to what temperature and what length of time is needed effectually to kill these toxins. Recent investigations, both here and in America, indicate that the thermal destruction-points probably vary through a quite wide range of temperature, dependent upon the medium in which the toxin exists, and upon the nature of the toxin itself. It is therefore important that food-canners should invariably treat the material at a sufficiently high temperature for the necessary length of time to be certain of the destruction of any bacterial toxins which might be present. As none of the bacteria belonging to the *Salmonella* group are sporulating organisms, no difficulty should be experienced in destroying the organism itself by heat. Few bacteria in vegetative form can resist temperatures in the region of 70° C. for more than a few minutes.

Botulism

Much has recently been published concerning this disease, and about *B. botulinus*, the cause of it. The facts that this bacillus is a spore-bearer, and that the spores are particularly resistant to heat (and further, that the organism is an anærobe), make it especially difficult to destroy in canned foods where the conditions are suitable for anærobic growth. It is one of the few, if not the only anærobic spore-bearing organism which produces a most powerful toxin. Fortunately outbreaks of botulism in this country are exceedingly rare ; there is only one authentic case—that at Loch Maree in 1922. Recently the term botulism has been loosely applied to one or two cases of food-poisoning in which the presence of the toxin produced by *B. botulinus* has been open to doubt.

During the past few years there has been a number of cases of illness caused by the consumption of food, both here and in America, in which the trouble has arisen through the infection of the material with a toxigenic staphylococcus. Various foods have been found to be the cause, such as ice-cream, sponge-cakes, chicken broth, ox tongues, and other ready cooked meats, and bottled prawns, etc. The illness is not usually prolonged, and the patient quickly recovers, but the symptoms are severe at their onset. No fatal cases, so far as is known, have occurred.

The toxin is apparently extracellular, since it can be proved to be present after the removal of the organism by filtration. Whether the toxin is produced by one particular type of staphylococcus, or by many types according to the conditions in which they exist (such as media, etc.) is uncertain and there also appears to be considerable doubt as to the thermal destruction point of the toxin. Dolman[21] states that two toxins are produced, one of lower thermal destruction-point than the other. At present much remains obscure, both as to the possible sources of infection, and as to the conditions necessary to allow of the formation of the toxin.

While it is now generally admitted that canned foods are the cause of less illness than is food in any other form, it happens on occasion that the canned-food bacteriologist is called upon to report on food which is alleged to have caused sickness. It is therefore necessary to include in this survey of the subject some particulars about " food-poisoning bacteria." These organisms belong to the genus *Salmonella*, which according to Bergey[8] consists of the following species :

B. suipestifer, B. columbensis, B. pullorum, B. abortivoequina, B. icteroides, B. gallinarum, B. enteriditis (Gartner), B. schottmuelleri, B. anatis, B. aertrycke, B. typhimurium, B. verboda, B. watareka, B. paratyphosus (A and B), *B. Hirschfeldii, B. psittacosis, B. Archibaldii, B. Woloniae, B. Giumai, B. Morganii, B. fœtida.*

Of the above, the most commonly occurring varieties are *B. paratyphosus* (A and B), *B. aertrycke, B. enteriditis (Gartner)* and *B. suipestifer.*

All the members of this group possess almost exactly the same morphological characteristics, and different species can only be identified by their serological reactions.

Poisoning can arise in two ways as the result of food infection by the *Salmonella* group. The organism itself is present in the vegetative form, or there exists in the material a toxin produced by the action of the bacillus. Savage[22] states that " when illness is caused by canned foods the characteristic feature is the high proportion due to toxins only, no living bacilli being present." This he attributes to the fact that " the processing given is usually adequate to kill non-sporing bacilli, like the members of the *Salmonella* group, but may be insufficient to destroy their toxins, which are known to possess marked resistance to heat." He classifies 51 cases of poisoning attributed to canned foods as follows : 16 due to living bacilli, 27 to *Salmonella* group toxins, and 8 the cause of which was uncertain.

Morphological Characteristics of Salmonella Group Organisms

The morphological characteristics of all the organisms of the *Salmonella* group are the same, so that by ordinary methods it is not possible to identify the different species. Positive identification can be obtained only by the employment of serological tests, which, of course, entail the use of live animals. It is seldom that this facility is at the disposal of the food-canning technologist. Further, the successful carrying out of the test requires great skill and much experience. If the necessity arises to carry out an investigation of this nature, it is advisable to call in the help of a specialist in serological work. It is, however, within the province of the canning bacteriologist to apply such tests as may be needed to ascertain if *Salmonella* group organisms are present in the food under examination, and the following particulars will prove of service.

Habitat. The majority of members of the group exist in the intestinal tract of living animals. Hence the necessity for great care at the time of slaughter, to avoid the possibility of the contents of the intestine coming into contact with the edible portion of the carcase. (It is probable that there is room for improvement in this respect in many of the slaughter-houses in this country.)

Sporulation. None of the group is a spore bearer.

Motility. There is some doubt in regard to the motility of a few members of the group, but the majority are certainly motile, and possess four or five flagella. It is possible that the power to move may be dependent upon the age of the cultures.

They all grow readily in ordinary media, such as nutrient broth, agar and gelatine ; and incubation should be carried out at 37° C. in order to obtain optimum conditions. Further, the reaction of the medium should be adjusted to a p_H of 7·0 (neutrality).

The appearance of the colonies on gelatine and agar plates is much the same—a thin, nearly transparent film, greyish-white in colour. No liquefaction of gelatine occurs.

Nutrient broth is uniformly clouded, no scum appearing even in old cultures.

In litmus milk, some slight acidity is at first produced, usually during the first 24 hours of incubation, but no coagulation of the casein occurs, and the acidity soon gives way to a permanent alkalinity at the end of about 48 hours, although in some instances the reversion from acidity to alkalinity may not take place for a period of days or even weeks.

Behaviour with Sugars. All the members of the group ferment glucose, and a few dulcite, but they are without this action upon lactose and saccharose.

*Indol Reaction.** Negative.

Voges-Proskœur Reaction.† Negative.

Thresh, Beale and Suckling,[24] state : " It should be noted that absolute reliance should not be placed upon fermentation reactions." As regards dulcite in particular, according to Bruce White[14] some strains of *B. aertrycke* and *B. enteriditis,* and most strains of *B. suipestifer,* do not ferment dulcite, while others, as *B. paratyphosus* (A) ferment this " sugar " very slowly.

Oxygen Requirements. Facultative ærobes.

In regard to the thermal death-point of these organisms, it must not be overlooked that recent work in America and elsewhere is indicating that the death-point and death-time of bacteria appear to show some variation according to the existing conditions, and it is possible that the data on this subject may need to be adjusted. The presence of living organisms of non-sporing species of bacteria in cans which have been submitted to a high process, strengthens this view.

Moulds Causing Food Spoilage

Among the " enemies " with which the food manufacturer has to contend, moulds certainly take a very prominent place, and, on account

* The formation of indol from albumin by certain organisms sometimes constitutes an important specific characteristic. To observe the indol reaction, it is desirable to grow the organism in peptone water, or in a fluid medium containing peptone. To the culture is added about 5 drops of concentrated acid, followed by 2 c.cs. of a 0·01 per cent. solution of sodium nitrite in water. The formation of a pink colour indicates the presence of indol, which sometimes appears only slowly. Indol is produced as the result of an attack by the organism upon tryptophane, which is one of the amino acids of protein. The compound possesses the formula C_8H_7N. Organisms of the *proteus* and *coli* groups ·are typical indol-producing bacteria.

† The Voges-Proskœur reaction test is an important one, for it serves to differentiate between organisms of the *B. lactis aerogenes* group and *B. coli,* the latter giving no reaction. For the purpose of carrying out the test, the organism is cultured in glucose bouillon. After 48 hours' incubation, approximately 0·5 c.c. of potassium hydrate solution is added. A red fluorescence slowly appears if the reaction is a positive one. According to Harden the production of the colour is due to the formation of acetyl-methyl-carbinol, which in the presence of potassium hydrate is oxidised by the atmospheric oxygen to diacetyl ; this in turn reacts with a constituent of the peptone (unknown) to produce the eosin-like colour.

of their nature and wide occurrence, the problem of checking their activity is one of much difficulty. The substances commonly employed as fungicides are quite unsuitable for use with food, and therefore special methods have to be resorted to if losses are to be kept within reasonable limits.

The moulds are members of the great family of fungi, which is itself one of the most important classes of the *Thallophyta*, the other being the *algæ* (one example of which is the seaweeds). The outstanding difference between the two classes is that the fungi contain no chlorophyll.

The typical vegetative structure of the fungi is a filamentous, and much branched, thallus called a mycelium. The filaments or threads of which the mycelium consists are known as hyphæ. The mycelium, and sometimes its hyphæ, may be septate or non-septate ; in most instances it is cœnocytic ; even where it is septate the segments contain several nuclei, and are hence cœnoceptic cells. Their walls do not consist of ordinary cellulose. It was formerly considered that they were built up of a substance called fungus-cellulose, but more recent investigations indicate that it is probably chitin.

Nutrition. Possessing no chlorophyll, the moulds can make no use of the carbon dioxide of the atmosphere, and thus derive their carbonaceous food substances from external sources by breaking down complex organic compounds. This also to some extent applies to their nitrogen requirements, but they can assimilate comparatively simple nitrogen compounds, such as the organic salts of ammonium, which they prefer to nitrates.

Mode of Life. The moulds may live as either parasites or saprophytes, but are liable to adapt themselves to circumstances. In a parasitic fungus the hyphæ may either penetrate the cell of the host, or simply force their way into the intra-cellular spaces. The power of breaking down the cell walls is due to the secretion of a ferment which acts upon the cellulose. The hyphæ of saprophytes ramify through the decaying organic substance, or may grow in organic solution.[26]

Reproduction. Lower members of the group of fungi (such as the mould *mucor*) possess both sexual and asexual methods of reproduction, but in the higher fungi sexual development is less evident.

The ability of moulds to grow at relatively low temperatures, although the growth may be slow, and to multiply in media of high osmotic pressure, or of low p_H value, fits them to grow in a number of food products in which some treatment may have been employed to check the ravages of bacteria, as for example the salting of meat. They may be found existing in such foodstuffs as smoked meats, hams, bacon, jam, jellies, butter and cheese, pickles, pie crusts, stored fruits and vegetables. The period of time during which, and the humidity of the atmosphere in which storage takes place, have an important bearing upon mould development. In commercially preserved foods the reduction of the air in con-

tact with them to a minimum, and the height of the temperatures employed during the process of preserving are sufficient to eliminate moulds as a frequent source of spoilage, but home-made jams and home-bottled fruits frequently develop mould growth.

Moulds are readily able to adapt themselves to their environment. They will grow on damp wood, or even in dilute acids containing the necessary amount of organic material for their nourishment. As an example, *Penicillium glaucum* will grow quite readily in a 4 per cent. solution of sulphuric acid containing a small quantity of lactose or other sugar, with traces of a nitrogenous compound.

The most commonly occurring moulds are *Penicillium glaucum, Mucor mucedo, Aspergillus glaucus* and *Oidium lactis,* but other and less frequently occurring moulds are from time to time met with, usually associated with foods which have undergone special treatment, e.g., the chilled storage of meat.

Penicillium Glaucum

This is perhaps the most commonly occurring of all moulds, and may be observed as a bluish-green fur on jams, bread, etc., and many other damp surfaces. Fig. 67 is a micro-photograph of the organism taken from the surface of a decomposing sausage.

The mycelium consists of horizontally arranged straight or slightly branched, jointed filaments, from which the spore-bearing hyphæ stand up vertically, dividing at their upper ends into several branches (basidia), from which fine processes branch off (sterigmata) in the shape of a hair pencil, and are segmented at their ends into rows of fine globular spores (conidia). Wind currents cause movement of the hyphæ and dispersion of the spores, which give rise to new individuals. Under suitable conditions *Penicillium glaucum* spreads with remarkable rapidity, and a piece of infected bread will be covered with a visible mould growth in less than 48 hours.

Mucor Mucedo

This form occurs especially in connection with organic putrefactive changes, and may nearly always be found on decaying horse dung. This mould is illustrated in Fig. 68. It appears as a white, or dirty white, mass of fine hair-like filaments, some of which may be three or more inches long, and carry at their tips brownish-white swellings which contain the reproductive elements. Microscopically the plant consists of non-septate elements. The mould possesses sexual and non-sexual forms of reproduction, the latter being the more common. One of the filaments grows out, at its termination a septum forms, and a globular swelling (the sporangium) appears. This sporangium possesses a definite membrane. Within it, from the septum, grows a club-shaped mass of

Fig. 67

PENICILLIUM GLAUCUM ON SURFACE OF DECOMPOSING SAUSAGE.
× 1125

Courtesy of " Food "

FIG. 68

MUCOR MUCEDO, SHOWING FINE HAIR-LIKE FILAMENTS WITH SWELLINGS AT THE TIPS. × 120

Courtesy of " Food "

FIG. 69

ASPERGILLUS GLAUCUS, SHOWING SPORES IN A COMPACT MASS OR
HEAD AT THE TIP OF THE HYPHAE. × 900

Courtesy of " Food"

protoplasm called the columella, to which are attached the swarm-spores formed from the breaking up of the rest of the protoplasm. When ripe, the brood cell bursts, the brown swarm-spores are cast off, and from each a new individual arises.[27]

Oidium Lactis

This is a mould very commonly occurring in sour milk and upon butter, and sometimes in imperfectly prepared lard. It appears as a white fur-like growth, and spreads rapidly. Microscopically it is found to consist of filaments, which may be branched and are broken up at their ends into short round, oval or rod-shaped segments commonly known as oidia. These behave like spores, there being no spore-bearing organs present. The mould grows upon gelatine without producing liquefaction of the medium, and gives off an odour not unlike sour milk. It appears to grow in milk without producing any marked change in that medium.

Aspergillus Glaucus

This mould is also commonly associated with putrefactive changes in vegetable matter, and the genus aspergillus will be frequently encountered wherever mould is found growing. Its chief characteristic is in the arrangement of the conidia and the conidiophores. An unbranched conidiophore arises from an enlarged cell of the vegetative mycelium, and terminates in a swollen portion, the vesicle. From the latter are given off a number of little stalks or sterigmata, having a characteristic ten-pin form, which in turn bear the chains of conidia. This arrangement presents the spores in a compact mass or head at the tip of the hyphæ. It is clearly shown in Fig. 69.

Byssochlamys Fulva

This fungus causes spoilage in canned fruit by causing tissue destruction, resulting in complete pulping. The result is particularly spectacular in bottled fruit. The fruit may give all appearances of perfection but it will, if deterioration has proceeded far enough, fall to pieces on shaking. Control in the orchard would not seem to be possible, according to Hull,[37] fruit affected has included gooseberries, cherries, blackcurrants, plums, damsons, raspberries, strawberries and loganberries. Chemical means of destroying the spores have been investigated but found inferior to sterilisation by heat. Hull[38] has found that increased sugar concentration in the syrup renders the spores more heat resistant but retards the growth of mycelium. High temperatures in canning are most effective,[37] 180° F. being regarded as sufficient in normal cleanly cannery practice. Should the cannery become heavily infected then a higher temperature, up to 200° F., should be adopted. The following morphological characteristics are taken from the paper by Olliver and Smith.[39]

Growth. Colonies grow well on most solid media, better on natural than on synthetic.

Temperature. Growth most ready at 30° C. and 37° C. On liquid synthetic media fairly slow at 20° to 25° C. better at 30° C., at 37° C. the spores are readily wetted by liquid media and growth is very slow until the submerged mycelium reaches the surface.

Form. Surface white, then buff to pale brown in central areas, slightly floccose or funiculose. After 7 to 10 days shows clusters of asci visible to the naked eye as minute globose masses partially embedded in mycelial felt ; reverse slowly turning pale brown : conidial fructification of the *Pæcilomyces* type, conidiophores being variable in length arising as side branches from long trailing hyphæ, simple or variously branched, 2 to 3μ in diameter, leaving whorls of sterigmata or solitary sterigmata at various points along the length, sessile or on short side branches ; sterigmata, short tubular or much swollen at the base and terminating in long slender tubes, frequently curved or bent away from the main axis up to 25μ long and usually 2 to 3μ in diameter but occasionally up to 7μ ; conidia, one-celled hyaline, ovate to elongate, very variable in size but mostly 4 to 9μ by $2\cdot3$ to $2\cdot5\mu$, borne in very long unbranched tangled chains ; asci, very abundant, roughly globose clusters, ovate, 6 to $6\cdot5\mu$ by $4\cdot3$ to $4\cdot5\mu$.

It is quite common to find several species of moulds growing in juxtaposition, and it must be clearly understood that many other varieties, in addition to those briefly described, are quite likely to be met. Moulton[28] mentions twelve different kinds to be found in meat-manufacturing establishments in America.

The fact that most moulds will grow readily, given conditions of warmth and humidity, and that activities of practically all of them can be checked by taking certain precautions, makes their specific identification somewhat less important than that of the bacteria, which possess a multitude of special properties. But occasions arise where the identification of a particular variety is called for, in which event the reader is referred to works dealing specially with fungi, such as "Moulds, Yeasts and Actinomycetes" (Henrici).

It should be remembered that moulds frequently produce marked discoloration of the material in which they are growing. Thom and Shaw,[29] call attention to the formation of orange coloured patches produced in butter by *Oidium lactis*. Duckwell[1] isolated a yellow mould from the surface of jelly, and a mould forming violet patches in lard has also been isolated. "Black spot" on frozen meat has been the subject of special investigations, both in this country and in America. Klein[30] attributed the formation of the spots to the growth of a yeast of the genus saccharomyces, but later Brooks and Kidd,[31] found the spots to be due

to the presence of *Cladosporium herbarum*, which mould grew very slowly at 18° F. and produced the black spots in about six months. The spots, which are readily removed by brushing, appear to have no deleterious effect upon the quality of the meat.

It appears probable that the meat may become infected at the time of slaughter, and Wright[32] states that if great care be taken at this time, and the storage temperature be kept not higher than — 9° C., the meat could be kept for years without the formation of black spots.

Thermal Death-Point

A study of the literature shows that the majority of moulds are destroyed if held at a temperature of 60° C. for a period of 30 minutes, and that the spores will not withstand a very much higher temperature than 65° C. for a period of 10 minutes. In those factories where the materials are subjected to a cooking process, the destruction of mould is not a difficult matter, provided that subsequent infection is prevented, and herein lies the greatest danger. Mould spores are omnipresent; a fact readily shown by exposing a sterile gelatine plate to the air almost anywhere for a few minutes. Unless the manufacturer protects his products from exposure to the air subsequent to their being cooked, or otherwise treated by heat, spoilage by the growth of mould is inevitable. It is also possible for premises to become specially infected with moulds, and vigilance is needed to see that this does not occur. The condition may be brought about by dampness such as that due to a leaky roof, and the presence, in the form of dust, of materials which encourage the growth of moulds. As an example may be quoted a wooden-lined ceiling in a factory producing milk powder. An infection actually occurred in such premises and caused irreparable damage before it could be checked. Many tons of butter and other products became infected, and the mould propagated with such rapidity that spoilage took place within forty-eight hours of the infection of the materials. The remedy is, of course, cleanliness. For utensils thorough washing in boiling water is all that is needed but the premises need treatment with a fungicide at regular periods. Sodium hypochlorite is one of the safest and most efficient cleaning agents which can be used. A 0·5 per cent. solution of this substance will be found to destroy all mould growths in 5 minutes, provided that there is not an undue amount of other organic matter present. It is usually not necessary to use the hypochlorite in such strength provided extraneous organic matter is first removed ; a 0·25 per cent. solution will prove quite effective.

In quite a number of factories it is now the practice to cool, wrap and pack the perishable goods in filtered air, the wrapping material and boxes being first subjected to a treatment by heat, or hypochlorite, to destroy mould spores which may be present upon them. Efficient air filtration will remove all the spores of moulds and incidentally 95 per cent. of the

bacteria. Materials so treated in a clean factory will never go mouldy provided that they are kept wrapped until they pass to the purchaser.

There is considerable doubt as to whether mould growth in itself is ever harmful, but it certainly makes infected food unsaleable, and every possible step should be taken to prevent spoilage from this cause. Control in the factory is a comparatively simple matter, but once the goods leave the premises, subsequent infection depends upon the treatment they receive at the hands both of the vendor and of the purchaser.

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CHAPTER XIII

Effect of Canning upon Nutritive Values

In as much as canned foodstuffs are cooked foods, cooked under extremely carefully controlled conditions, it is probable that the nutritive values of the raw food, taken as a whole, are better preserved than they are in domestic cooking : apart, altogether, from the most important consideration, that they will keep in their cooked state for a long time, even for many years. Some authorities, Kohman[1] for example, consider that they have now accumulated sufficient experimental evidence as to amount to proof of their superior nutritional qualities. So far as the inorganic constituents are concerned it must be regarded as obvious that the canning process properly carried out can have no effect. Kohman[1] has, however, advanced the thesis that canning may render the calcium and phosphorus present in the raw food somewhat more available. The major portion of the food, the organic matter, equally obviously undergoes the usual changes promoted by cooking : the fibrous material that constitutes the indigestible residue or " roughage," to use a favourite pseudo-medical term, of all foods is softened, and the food thereby rendered more digestible. The cooking is thorough and the food more easily digested and more easily assimilated. Kohman[1] publishes some most interesting photographs of rats fed only upon canned foods, compared with rats fed upon raw and home cooked foods, showing considerably superior growth on the part of those upon a canned dietary. " The modern short cooking period prescribed for vegetables and fruits," he says, " should be recognised as being a relatively mild heat treatment compared with the process necessitated for sterilisation in canned foods.

" It should be borne in mind that for canning, such products as peas, lima beans, green and wax beans, etc., are harvested in a distinctly less mature condition than for market produce. Moreover, these vegetables as well as others such as spinach, turnip greens, cauliflower, carrots, etc., which are among the chief sources of calcium in the absence of milk, are held in the raw state after harvesting for materially longer periods as market produce than is the case when used for canning. Since this condition is conducive to the toughening of the vegetable fibre, the adsorptive attraction for calcium may be affected." Except for Kohman's work little, if any, experimental data are available upon this aspect of the subject, nor is there much that is of value upon the chemistry of cooked

foods in general.   Attention has been chiefly directed to raw foodstuffs, and for them there is an extensive literature.

When we come to the subject of vitamins and their survival in canning then we are presented with a different picture : the literature is already large and is increasing rapidly.   It is not our purpose to review it in more than sufficient detail to give the general findings of workers in this field. Here again Kohman is the recognised leader.   And he claims, in the paper already referred to as well as an earlier one,[2] that for rats " either a diet more nearly the optimum than usual for these species results from the combination of foods selected, or there is some heretofore unrecognised advantage in a diet made up wholly of canned foods.   The evidence indicates that canned foods may supply every dietary requirement, including vitamins B and C, so often referred to as heat labile."   Whether the results obtained upon rats would be reproducible in similar experimental work upon man cannot be told, but it must be borne in mind that the major vitamin experiments have proved similar, to the considerable advance of the general well-being.

To estimate the probable effect of canning upon the vitaminic content of the raw foodstuff the nature of the cooking involved must be borne in mind.   It is generally considered that the stability of the vitamins is as follows :

VITAMIN A

Not destroyed in canned meat, bottled vegetables and fruits.   The same is true of carotene.   It is gradually destroyed by heating in air but not by heating in a vacuum.   Stable to sodium carbonate and alkali.[3] In the absence of oxygen, vitamin A will withstand heating for 12 hours at 120° C. ; in the presence of oxygen its heat resistance is greatly weakened.   According to Drummond,[34] its loss from butter heated to 37° C., is very considerable, whilst Hopkins[35] found it to be completely destroyed by heat and aeration at 120° C. at the end of four hours.

VITAMIN B COMPLEX

Little or no destruction on exposure to 100° C. in acid or faintly acid media of B_1 unless prolonged.   Readily destroyed by alkali even at low temperatures.[4]

In slightly acid media (p_H 4·5 to 5·0) B_2 or G, is comparatively stable : about half is destroyed at 120° C. after six hours.   At greater acidity the destruction is more rapid.   In alkali of all concentrations, destruction is complete after a time : it survives one hour at 120° C. in " strongly alkaline " solution.[4]   It may be that the salt concentration of the solution has some effect.

VITAMIN C OR ASCORBIC ACID

Very sensitive to oxidising agents and air.   Inactivation takes place

rapidly in alkaline solution in air, but not under anærobic conditions. At p_H 12·5 decitrated lemon juice lost 80 per cent. of its potency on exposure to air for half an hour and the whole of it in 3 hours, whereas when preserved anærobically for 24 hours it had not appreciably decreased in potency.[4] On the other hand recent work by Ahmad,[5] MacHenry and Graham,[6] and Guha and Pal,[7] shows that several fresh foods such as cabbage, cauliflower, carrots, bel (a common Indian fruit), etc., give a higher ascorbic acid value on being cooked or boiled with water, as estimated titrimetrically. It is thought that part of the vitamin in the natural foodstuffs is present in a combined state, and is released on cooking. The increase, according to the last workers, may vary between 50 and 100 per cent.   If this is so it might account for the high vitamin C content given in the literature for so many canned vegetables. On the other hand, Olliver, in a most important paper setting out results that show increase in ascorbic acid on canning, is of the opinion that the phenomenon may be due to the cell contents being more readily extracted as a result of the softening effect of heat upon the food tissues.   Olliver found this increase in both vegetables and fruit.   The possibility should certainly be borne in mind when considering figures of this kind. Kohman's work would seem to be additional proof.

Synthetic ascorbic acid has been added[9] to fruit and vegetables low in this vitamin before they were processed to test how far it would be destroyed in the normal canning operations, and the results would seem to be of first class importance.   The canned product was tested biologically.   Added to runner beans it was found that about 25 per cent. of the addition was destroyed and most of it was taken up by the solid part of the pack.   In spinach the loss was not great and the ascorbic acid was distributed between the solids and the liquor.   In apples the loss was about 25 per cent., and in apple jelly the loss was 10 to 20 per cent.

VITAMIN D, CALCIFEROL

Appears to be one of the more stable, not being destroyed by oxidation, heat, acid or alkali.[3]

VITAMIN E

Resembles vitamin A in its resistance to heat.   Undamaged by distillation *in vacuo* at 250° C., by exposure in air for two hours at 170° C., by auto-claving at 20 lbs. per sq. in. for two hours, by strong acids. It is destroyed by oxidative changes which accompany development of rancidity of oils and fats.[4]

It will thus be appreciated that the effect of the canning process is likely to be small upon the vitamin value of the majority of foods, since the conditions are not such as to lead to their complete destruction unless the canned product is stored for several years.   Some diminution on

prolonged storage is probable although not certain. Canning may however increase the available vitamin C content of some fruit and vegetables. Stamping with the date of processing has been advocated.[3]

Some idea of the probable quantitative value of a canned food may be estimated from a knowledge of the vitamin content of the food and the possible destruction or increase likely to take place on canning. For information concerning the raw foods, the tables and detailed summaries given in the various standard works upon the vitamins should be consulted.[10 and 4] But it cannot be too strongly emphasised that every food varies in its vitaminic content, according to climate, variety and maturity. For this reason biological or other assays (when possible) should be carried out upon the canned product before any specific claims concerning a particular pack are made. Such work is difficult and laborious, needing special technique, and the average canner who may want information should commission the special laboratories who have facilities for such work. These laboratories are of international repute and their work thoroughly reliable.

Vitamins in Canned Fruit and Vegetables

For the best examination of the persistence of vitamin C on canning, the reader should refer to Olliver's paper.[8] There the effect of canning and subsequent storage is examined for blackcurrant, strawberry, orange juice, gooseberry, loganberry, raspberry, apple cortex, greengage, pear, plum, melon, redcurrant, sprouts, asparagus, spinach, potato, broad bean, turnip, pea, runner bean, stringless bean, onion and carrot. The destruction of vitamin C is comparatively small, and the process results in frequently equal distribution between solid and liquid.

Apple is said[3] to retain its antiscorbutic properties, the minimum quantity to protect from scurvy being one-third of an ounce per day for a guinea pig.

Apricot has been found[11] to contain one international unit of vitamin A in 35 mgs. of Oklahoma canned apricots.

Beans have been found[3] to have 0·4 mg. of vitamin C per gm.

Beetroots, strained, are said[12] to contain 3·3 international units of vitamin B, and 3·3 of B_2 per ounce.

Cabbage is said[3] to protect a guinea pig from scurvy in quantities of $\frac{1}{4}$ ounce *per diem*.

Carrot, strained, has been found[12] to contain 4·3 international units of vitamin B_1, and 2·5 units of B_2 per ounce.

Cherry, varieties Moutmorency and Early Richmond, grown in Kansas, are said[13] to be fairly rich sources of vitamin A. Canned by the cold pack contained 2 to 4 Sherman units per gm.

Orange juice is said[3] to give protection against scurvy in quantities of one-twentieth of an ounce per day for guinea pigs. Packed by a

Florida canner it has been found[14] equal in vitamin C potency to fresh juice. Orange juice prepared by a special process[15] and canned, was found, on titrimetric estimation with dichlorophenol-indophenol, to decrease slightly after storage for nine months at room temperature.

Peas have been found[12] to contain 7·8 international units of vitamin B_1, and 7·5 to 8·6 of B_2 per ounce. Another writer[3] gives the vitamin C content as 0·05 mgs. per gm., the antiscorbutic dose for a guinea pig being one-third of an ounce *per diem*.

Pineapple, the guinea pig protective dose is given as 3 c.cs. *per diem*.

Pineapple juice, one brand has been approved by the Committee on Foods of the American Medical Association[16] (a body said to be very jealous of giving its approval to proprietary brands claiming medicinal properties) who stated that vitamin C content of the pineapple had been slightly reduced but that it was a good source of A, B, C, and also contains B_2.

Rice conserve, to which a fir-needle concentrate had been added[17] contained 76 to 111 international units of vitamin C per kg. Daily doses of 180 to 260 gms. corresponds to daily requirements of human beings.

Sauerkraut has been examined[18] and some brands found to have practically duplicated their vitamin C content on canning. This is interesting in view of the work of Olliver, Guha and others quoted above. Other brands were found to have no antiscorbutic value when fed to guinea pigs. No correlation was found between vitamin C content and factory processing.

Spinach has been shown[12] to contain 2·5 international units of B_1 and 7·5 to 11·8 of B_2 per ounce. Vitamin A content of cooked and canned spinach are said[19] to be identical ; there was more B_1 in canned than cooked spinach, and the same result was found for vitamin C : 30 gms. of canned against 10 gms. of raw, protected guinea pigs from scurvy. The Plimmers[3] give the vitamin C content as 0·05 mg. per gm.

Tomato seems to be the favourite vegetable of the literature. This is perhaps natural in view of its high vitamin C content. The Plimmers[3] give the antiscorbutic dose, for a guinea pig, of fresh canned tomato juice as 8·5 gms. per diem, and after keeping for 4 years, as 10·0 gms. Other workers[20] compared the 1933 and 1932 packs upon guinea pigs and found that 4 c.cs. of the former gave antiscorbutic protection and 2 c.cs. of the latter. They also found that the B_2 content was 0·21 international units per gm., whilst canning had no effect upon the vitamin A content. The Plimmers quote Goldberger as finding one quart a day being the anti-pellagra dose for human beings (vitamin B_2 is the anti-pellagra vitamin). They also quote Hess, on the antiscorbutic value of the juice, as saying that two tablespoons were protection for infants over three months of age. Another worker[12] has found the strained juice to contain 20 to 24 international units of B_1 and 6·7 of B_2 per ounce. Italian

canned tomato paste imported into Norway for canning with fish has been examined[21] : the antiscorbutic value was found to be erratic, the daily protective dose being 7·5 to 18 gms. for guinea pigs. The concentrated pastes (40 per cent. solids as against 20 per cent. solids) were found to have no additional vitamin C.

Vegetable Soups have been found[12] (the term is pleasantly vague) to contain 3 international units of B_1, and of B_2 per ounce.

Vegetable Purées have been approved by the American medical profession as valuable additions to the infant dietary.[22] They were launched with suitable advertising and the output speedily reached several millions of cans.

Vitamins in Canned Fish

Little appears to have been done on this subject. A modified Carr-Price test has been carried out by Lunde and others,[23] upon a 20 per cent. solution of various fish products and the vitamin A content determined in this manner. It was found that brisling sardines showed no diminution on canning, even after two years' storage either in tinplate or aluminium cans.

Canned salmon has been examined[24] by expressing the oil in the flesh and carrying out biological tests. It was found " quite apparent that there is more vitamin D in canned salmon than in the cod liver oil used for animal and human feeding."

Milk

Sweetened condensed milk prepared at a low temperature and *in vacuo* is equal in antiscorbutic value to fresh milk : unsweetened condensed milk is frequently heated to a higher temperature, and so loses about half its vitamin C.[3] The vitamin A of condensed milk, it will be appreciated, is not likely to be less than that of the raw milk in view of the stability of this vitamin. Sherman and Smith[10] say on p. 272, that the vitamin A content of condensed milk averages twice that of the raw milk ; being about 4 units per gm. as against 2 per gm. If they are correct then the evaporation concentrates the vitamin A, and has little or no destructive effect upon it.

Meat

A survey of the available literature makes it apparent that the subject of vitamins in canned meats has not so far received the same attention as bestowed upon that of vitamins in canned fruits and vegetables. This is perhaps somewhat surprising, because preserved meats to-day form a very important item in the diet of many families, and their consumption is rapidly increasing. Before passing to a consideration of our present state of knowledge in regard to the vitamin content of canned meats,

a summary of the occurrence of these substances in fresh meat will be helpful.

Vitamin A is apparently abundant in beef, but according to Hoagland and Snider[25] its presence in lamb and mutton is doubtful, and Wright,[26] Hoagland and Snider,[25] and Sherman,[10] regard its presence in pork as problematical.

Vitamin B_1 has been found by Hoagland[27] in fresh pork to an extent approaching richness; in veal by Sherman.[10]   It is present also in most other meats.

Vitamin B_2.   Hoagland[28] reports the presence of this vitamin in fresh pork to a considerable extent.   Goldberger and co-workers,[29] were doubtful of its existence in salt pork.   No further work appears to have been carried out regarding its occurrence in other meats.

Vitamin C.   Goldberger and co-workers[29] and Aykroyd and Roscoe[30] both found vitamin *C* to be present in beef.   Hart, Steenhock and co-workers[31] found it in chicken.   Hoagland[28] found it to exist in pork.

Vitamin D.   Not found in any animal flesh.

Vitamin E.   Beef is reported to be a source of this vitamin.[32]

Probabilities of Occurrence

It would appear, therefore, that with the exception of vitamin *D*, the vitamins are present in one or the other of the kinds of meat which lend themselves to canning, and unless destruction has taken place in the course of manufacture, they should be found to persist in canned meats.   Unfortunately, the information available on this point is somewhat meagre, but a general indication as to the probability of their occurrence in this article of food may be obtained by a consideration of the viability of the vitamins to heat, oxidation, etc.

The persistence of vitamin *A* in canned meats must depend upon the manner in which the canning has taken place, both in regard to the time and temperature of the process and the efficacy of the exhaust. The removal of as much as possible of the oxygen from the can must have a favourable effect upon the survival of the vitamin.

The heat stability of vitamin B_1 is considerable, but shows a great falling off in the presence of much moisture.   Nitzescu[33] found that it was practically destroyed in grain heated for one hour at 120° C. in the presence of moisture.   The existing reports of work carried out upon the occurrence of vitamin B_1 in canned meats are few, but Chick and Hume[34] report that they failed to cure pigeons of polyneuritis by feeding 106 and 112 grammes of canned beef, whereas the curative dose of raw meat was 30 grammes.   On account of its somewhat ready destruction by heat in the presence of moisture, it appears unlikely that vitamin B_1 can persist in canned meats, because of the high temperature needed for its process, and the abundance of moisture always present in the meat.

Thermostability of Vitamin B_2

Vitamin B_2 is usually considered to be one of the most thermostable of all the vitamins. It remains undestroyed by a temperature of 120° C. for 4 or 5 hours. Its presence in canned pork can therefore be regarded as highly probable, pork being one of the few fresh meats in which it is known to exist.

Little work appears to have been carried out in regard to the presence of vitamin C in canned meats, but it is well known that it is particularly susceptible to oxidation, although in the absence of oxygen heat has little effect. If, therefore, removal of the oxygen from cans of those meats which in the fresh state contain vitamin C has been effectually accomplished, some of this vitamin should persist through the canning process. It is, however, a matter of great difficulty to reduce the oxygen to a negligible factor in cans of food, particularly where the contents are of the nature of meat.

Vitamin E, present in beef to a marked extent, is remarkably stable to heat and chemical reactions generally, properties not shared by the other fat-soluble vitamins. It has been shown that it can withstand temperatures from 155° to 170° C. for a period of two hours, so that its persistence in canned beef may be regarded as highly probable, particularly in view of the fact that it is not readily susceptible to oxidation. No work appears to have been published upon the presence of this vitamin in canned meats.

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CHAPTER XIV

THE waste from the cannery may be divided into two kinds; the fluid effluent from the washing of fruit, vegetables, carcases and so forth, the washing of utensils and equipment and the washing of walls and floors; and the solid waste such as vegetable debris, fish and meat offal and other parts of the carcase that cannot be sold in the canned form. Where possible it behoves the energetic canner to utilise what he can of this material and convert it into saleable by-products; and to-day, this is undertaken on an extensive scale, so far as meat is concerned.

Fluid Effluents

It is not, at present, possible to win valuable by-products from these but, in view of their organic content, their disposal presents problems of no little difficulty, and in many instances of some cost. On the other hand, it must not be forgotten that the raw water has had to be paid for, and may even have been subjected to expensive treatment to render it suitable for canning purposes. If the effluent can be purified from organic matter sufficiently for re-use in any part of the process, at a cost below that of the raw water treatment, then obviously the installation of effluent treatment will speedily pay for itself and yield a profit. Where this is not possible it may still need treatment before the local authorities or other bodies controlling the discharge of effluent will accept it into their sewers or streams. And those bodies must obviously be consulted beforehand lest a worse fate befall the canner. In Great Britain attention to this matter is probably more urgent than elsewhere, in view of the extremely complicated position that has arisen, which although it would appear to be being straightened out yet demands considerable care.[1] In some districts organic wastes will not be taken into the sewers at all and in others it is readily accepted: between these two extremes there are infinite variations.

Effluents containing organic matter, as do those from the cannery, damage fish and other river life by seriously depleting, often to the extent of complete absorption, the oxygen in the water. Coupled with this of course there is the consequent anærobic decomposition of the organic matter with attendant formation of odour. The oxygen-absorbing properties of an effluent are usually expressed in units of biochemical oxygen demand (B.O.D.) of so many parts per 100,000 or per million.

226

Crude effluent from a milk factory, for example, has a B.O.D. of about 100 parts per 100,000.[3] The fermenting sap from a pea vine stack has a B.O.D. of about 40,000 parts per million.[2] The volume of fluid into which the effluent is discharged must be considered in relation to that effluent. For example streams swollen during cold weather can inoffensively assimilate much larger quantities of organic matter than they can in their low levels of the summer months. The latter may be considered as the critical period, and the data concerning it regarded as working basis for any discharge. Parker[2] considers that the washing water from a depot handling 10,000 gallons of milk *per diem* are equivalent to the domestic sewage from a population of about 1,000 people : the effluent from all the milk factories and depots in Great Britain in the summer months must be equivalent in polluting character to the domestic sewage from a town of about one million inhabitants. According to work published by the New York State Department of Health,[4] the organic content of effluent from the average two-line cannery, canning 4,000 cases of peas and tomatoes, is five to fifteen times that of an equal volume of domestic sewage, equivalent to that from a township of 10,000 people.

Treatment of such effluent may be undertaken on the usual lines adopted for domestic sewage, with certain necessary modifications : settlement in tanks, providing sufficient area is available ; the activated sludge and other biological methods ; chemical methods of flocculation with subsequent settlement. It is not our purpose here to describe these, and reference for details should be made to the standard works upon the subject. There have however been one or two recent developments of particular interest to the canner that may fittingly be touched upon : concentrated cannery effluent may be treated by fine screens followed by either trickling filter or chemical precipitation.[3] Using 40-mesh wire mesh screens or perforated plate screens, subjected to constant washing by water jets, or water and steam jets for tomato effluent, an area of 40 sq. ft. will purify 100,000 gals. of effluent in 12 hours sufficiently for safe discharge after dilution. This will yield about 75 cu. ft. of screenings *per diem* which may be spread upon the land. The effluent may however be passed through trickling filters and so effect removal of 80 to 95 per cent. of the biochemical oxygen demand when operating at the rate of 500,000 gallons per acre per day. The supply to the filter must be treated daily with 100 lb. of lime per 100,000 gallons in order to prevent fungal growth on the filter beds. Alternatively to the trickling filter the effluent may be subjected to chemical precipitation. According to Holmguist,[3] 7,000 to 10,000 lbs. of lime and 3,000 to 5,000 lbs. of copperas per million gallons, produces a " floc " which will settle in an hour in " fill and draw " tanks, or in two hours in continuous flow tanks. This removes 40 to 50 per cent. of the B.O.D. and the effluent may be discharged after a twenty-five times dilution. The sludge is bulky, having a volume ten per cent. of that of the original effluent, and a sludge

bed area of 3,000 sq. ft. is needed for drying the sludge from 100,000 gallons of waste. If, however, the sludge is previously de-watered by sedimentation and decantation in a 10,000 gallon tank, only half this area is needed. From this brief description it will be seen that the cost of purification may become an important item, and research is obviously needed to see whether the residues could not be made to yield by-products of some chemical value, however small.

In the condensing of milk considerable volumes of water are evaporated and its employment in the factory can be an important adjunct in efficient operation. With modern plant it is of distilled water quality and may be, and often is, used for condenser make-up water. The obnoxious effluent from the milk factory comes, as we have said, from the cleansing operations. Such effluent however was early found to deposit solid fatty matter in the top layers of percolating filters to such an extent as to choke them. Experimental work on a large scale by the Water Pollution Research Board, the Milk Marketing Board and the Scottish Milk Marketing Board, with the assistance of United Dairies, Ltd., was inaugurated in 1935, and, according to Parker,[1] has given promising results. By either an adaptation of the activated sludge process or by biological filtration the effluent may be purified to a B.O.D. of less than one part per 100,000, and fish can live in the final effluent.

In factories handling quantities of meat the chief impurity in the effluent, for reasons that will be apparent later, is fat. This is solid at normal temperature and the effluent may be easily cleansed sufficiently for discharge. It is the general practice to arrange for all meat cannery drains to pass into a catch pit so constructed as to allow the fatty matter to rise to the surface, where it can be skimmed off. The skimmings are treated in rendering plant with other fats, and any suspended protein material separated to yield fertiliser. Discussion of this properly comes under a later heading in this chapter.

Solid Refuse

This may conveniently be divided into two parts—vegetable and animal—in view of the difference in the treatment as practised to-day. Of these, the treatment of animal refuse has been developed far more extensively and the by-products are more valuable, some of them being of important medicinal application. With these last we shall not attempt to deal in detail since the small meat canner would be unable to justify the cost of plant and staff ; on the other hand it should be borne in mind that the various glands may be a source of profit if collected and stored in proper conditions, and even in the small cannery the reward is not unattractive. The Technical Committee on Abattoir Design, which reported in 1934, pointed out that the average factory abattoir should be well able to undertake the work, since the only equipment necessary is

a small refrigerated storage chamber kept at a temperature below freezing, and containers for acetone and other substances required in chemical preservation. With a minimum weekly kill of 320 cattle and other stock in proportion, sufficient quantities would be obtained to interest the average pharmaceutical manufacturing house. Tolle and Nelson[6] have examined the feasibility of extracting the oil from salmon residues, and state that the offal can be pressed to yield a first class medicinal oil at an attractive price. From experimental work they conclude the oil is equivalent to first class cod liver oil in vitamin A content and twice as potent in vitamin D.

Vegetable Waste

The bulkiest waste coming into the cannery is the pea vine. It is usual to make arrangements with the farmer to take it back after threshing for use either as a manure or as sheep fodder. Where it is allowed to accumulate, the effluent from its fermentation can add one more problem to those handled by the canner. On an average about 6,000 gallons of liquor drains every day from the stack of a two-line cannery, packing about 4,000 cases of peas. According to Holmguist[3] the organic content may be removed by chemical precipitation with 100 lb. of lime per 1,000 gallons.

Tomato residues have received a good deal of attention in the United States. The usual course is to turn them into manure. Skins and seeds are passed through a press, so that as much moisture as possible is expressed : the pomace is then dried for 15 minutes in a rotating drum dryer, heated by exhaust heat from the boilers. From the dryer the solid pomace is discharged to a grinder, and, after grinding is sacked. Prices for the meal were $20 to $25 per ton in 1934.[7] The Italian industry has long prepared a tomato seed cake for cattle fodder: this is prepared by mixing tomato skin meal with seed residue after extraction of oil from the latter. Rabak[8] investigated tomato seed oil obtained by crushing and solvent extraction, and found it similar in properties to cotton seed and soya bean oil, falling into the semi-drying class, having an excellent co-efficient of digestibility. At that time (1918) he estimated the available dry seeds in the United States at 1,560 tons annually, giving about 340 tons of oil and 1,200 tons of meal, which could be mixed with the corresponding 1,800 tons of skin meal.

Much work has been carried out upon the utilisation of citrus fruit residues, one by-product being pectin. Grape fruit seed is said to have been found, by the U.S. Department of Agriculture, to yield high quality salad oils as well as a solid fat. Fermented wines are said to be possible by-products.

Canned apple residues are said[10] to yield useful by-products, such as unfermented sweet cider, apple syrup, apple brandy, apple candy and so forth.

Unless one is able and prepared to work up by-products of this type the only alternative is dumping or incineration. The Birmingham Corporation[11] has worked out an alternative, by turning the vegetable refuse into fertiliser at an economic cost, and consideration of this might be worth while to the canner. The chief difficulty in handling vegetable waste is the economic reduction of the water present, amounting to 90 per cent., the bulk of which is enclosed in the vegetable cells, which must be ruptured. This is effected by a pulveriser in which the material is threshed by rotating arms against stationary grids through which it flows to a settling tank operated by agitators. The vegetable matter overflows and passes in an even layer on to a 40-mesh copper gauze drum, through which the loose water drains away. The vegetable matter is removed by a revolving brush on to a shaking conveyor to a pair of heavy rolls, weighing seven tons each, which break down the cell structure. From these the material is removed by a doctor knife and conveyed to two lighter rolls through which it passes in contact with a porous felt belt. This takes up the moisture and the dried debris falls off at the turn of the belt, containing about 25 per cent. of its original water content. Final drying is accomplished in a dryer consisting of a horizontal steam jacketed cylinder fitted with a central shaft, fitted with beater arms. The final product is a popular fertiliser containing 82 per cent. of humus-forming material.

Meat and Fish Waste

The by-products from meat and fish canning are most important. From the meat cannery where much slaughtering is undertaken come, for example, hides, wool, hair, bristles, edible fats such as oleo oil, oleomargarine, lard and so on, technical fats such as tallow, lubricants, soap, etc., bone meal, hoof meal, sausage casings, surgical and other gut, meat meal, blood meal, glue, gelatine and so forth.

The quantity and kind of the waste materials will be dependent upon the nature of the work carried out. Where slaughtering is part of the process, inedible offal, hair, hides and skins, condemned carcases, and so on will form much of the material with which the by-products departments will have to deal. As hides, skins and hair are almost always sold in an untreated condition, except possibly in the largest American packing houses, the method of dealing with them will not be considered here. Attention will be given to the manufacture of feeding meals and fertilisers produced from animal and fish offals, bones, etc.

Until comparatively recent times fish and animal residues were either used as fertilisers, sometimes without previous treatment, or used in the manufacture of glue, when the class of material permitted. About 35 years ago, poultry raisers found that egg production was materially increased by the addition of crushed bone and scraps of meat to the cereal

ration. Supplies of these were very limited and moreover could be kept fresh for only a few days.

When it was more fully understood what an important part was played by protein concentrates and mineral salts in the successful rearing of live stock, it became evident that animal and fish products represented an important source of these substances, but, to be available for general use, they would need to be prepared so that they would keep fresh and palatable for a long period. The earliest meals, which, although imperfect, were a considerable advance upon the use of crushed bones and meat scrap as such, were produced by treating the raw materials in a closed vessel with live steam under pressure. The fat or oil rising to the top of the vessel was skimmed off. Live steam treatment involved loss of much of the valuable nitrogenous matter present in the charge, which passed away in the condensed steam in the aqueous residue. The solid matter consisted very largely of the mineral matter of the bones and was dried and ground : much of it sold for fertiliser, the demand at that time for feeding meal of this class being small.

A big improvement in the product was brought about by the introduction of a method of dry rendering, by which the fish or animal residues are treated in a steam jacketed vessel, fitted with stirring gear. As cooking proceeds, as much as possible of the oil or fat is run off by means of a decanting cock, and when the charge is free from moisture, i.e., properly cooked, it is removed from the vessel and either pressed into cakes, or treated in a centrifugal machine with the object of removing a further quantity of oil or fat. This fetches a bigger price than the non-fatty residue. Provided the cooking has been efficiently carried out, the fat content of the meal is reduced to about 10 or 12 per cent. A large quantity of meal manufactured by this method is still offered for sale. One of the disadvantages of the centrifugal process is the tendency for formation of an emulsion between the small particles of fleshy material, which find their way through the filter cloth of the centrifugal machine, and the oil or fat together with some moisture. This emulsion is very troublesome to separate, and the residual greasy foots which settle out have to be returned to the cooking vessel with the next charge with consequent increase in the amount of finely divided material and, ultimately, of greasy foots.

Carefully conducted feeding experiments, carried out in Great Britain, and elsewhere, have conclusively proved that an excess of fat in the diet of live stock is most undesirable. Fish meal containing oil to an amount exceeding 5 per cent., even when mixed with the other materials forming the ration, is liable to give rise to " fishy " eggs and soft, oily bacon tainted with a fishy flavour. A large proportion of fatty matter in a ration frequently brings about digestive troubles. If, therefore, fish and animal meals are to be used with advantage they must contain little or no oil or fat.

A process was eventually evolved whereby the desired result was achieved (low fat content) by the application of the principles of solvent extraction.   The method is similar in some respects to the extraction of vegetable oils from crushed seeds, but is somewhat more complex because the raw material must first be freed from moisture before extraction can be undertaken.

Extraction Plant

There are at present two types of plant in use in this country, the first depends upon the sweeping out of the moisture from the charge by the
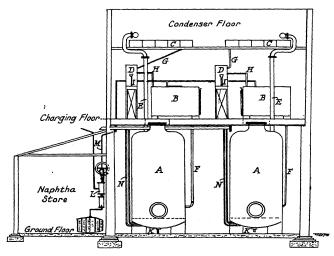
FIG. 70

DIAGRAMMATIC REPRESENTATION OF A BENZINE EXTRACTION PLANT
OPERATING THE SOLVENT VAPOUR PROCESS

From " Bone Products and Manures," by Lambert.

A, extractors ;   B, solvent storage tanks ;   C, condensers ;   D, separators ;   E, vapour outlet pipes ;
F, solvent supply pipes ;   G, pipe to condensers ;   J, manholes for emptying ;   N, steam supply pipes.

vapour of the solvent which is maintained at a higher temperature than that of boiling water.   In the second the moisture is removed from the material by rendering *in vacuo* and then washing the dried charge with the solvent.   Plants operating upon this latter principle are rapidly coming into use, although for special purposes treatment with the solvent vapour is preferred.   On this page is a diagrammatic illustration of what may be described as " The solvent vapour process."   It is usual so to arrange the installation that the charging floor is brought level with the floor of the offal receiving house.   This allows raw and finished materials to be kept entirely separate and makes

for general cleanliness and convenience. The finished meal is self-discharged from the extractor at the end, and here again, a satisfactory layout permits the discharge of the dry meal into a separate room for grinding and sifting.

The feeding meals produced by this plant are entirely satisfactory but the method possesses the disadvantage that it is rather heavy in fuel consumption and, unless very carefully controlled, leads to high solvent losses.

The second type of plant, in which the oil or fat is removed from the material after drying *in vacuo* is similar in layout to that shown in the diagram, except that the vaporiser is replaced by a vacuum pump. In this operation the solvent is used in its liquid form, and is therefore maintained at a temperature below its boiling point.

The boiling point range of the solvent is of importance. It must not be too volatile or there will be unnecessary loss, but if a solvent of high boiling point be used difficulty will arise in freeing the finished meal from the last trace of the solvent, and additional fuel will be needed for the purpose. Where the use of an inflammable spirit is permissible it is the practice to employ petroleum benzine with a boiling point range of from 90° to 110° C. It is important to use a solvent which leaves no residue upon evaporation, otherwise unpleasantly flavoured hydrocarbons may be left in the meal, which would seriously detract from its value as a feeding stuff. In premises where the use of an inflammable solvent is not possible, recourse may be made to halogen derivatives, such as trichlorethylene.

Solvent Extraction of Fish and Meat Waste

At certain seasons of the year oily fish offal is so fluid in consistency (particularly herring offal in July and August) as to be almost like water, and when allowed to stand in open vessels for a few hours a considerable layer of oil separates which can be removed by mechanical means. Because an extracted oil is not equal in quality to an oil which has separated out at ordinary temperature, settlement is allowed to take place, and, as much as possible of the oil having been removed, the residue, still very rich in oil, is transferred to cooking vessels, where it is rendered, preferably under vacuum. Under this treatment a coagulation of the protein matter takes place, and a substance, clay-like in consistency, separates readily to the bottom of the cooker, while the oil rises to the surface. Unless care is exercised during the cooking this process will be carried too far, and the oil become incorporated with the coagulated protein substances. The supernatant layer of oil is decanted, leaving the residue to be extracted with a solvent. Cooking is now usually carried out in separate vessels and, after settlement, the residue transferred to extractors, it being in a sufficiently liquid condition to allow of its flowing. Advantage is taken

of this property by placing the extractors immediately under the cooking pots. This pasty residue, although containing a considerable amount of moisture, will without further drying yield up its oil to the solvent. Further, the benzine solution of the oil will be almost entirely free from any suspended matter, usually a troublesome substance to remove.

Figure No. 71 is an illustration of a horizontal extractor of about 5 tons capacity. Attention is drawn to the decanting cocks, arranged diagonally on the end of the vessel. These are used, in the case of fish offal, to decant the separated oil and afterwards to decant as much as possible of the solvent solution of the oil. The remainder of this has to be withdrawn through straining devices fitted on the underside of the extractor. In practice the charge, in most cases after drying *in vacuo*, is washed with three or more successive portions of the solvent with the purpose of removing as much oil as possible. The solvent containing the oil is allowed to settle in vessels constructed with taper bottoms, into which the " foots " settle. The upper portion is then passed to the still; the solvent is driven off as vapour and is condensed and returned to the storage tank. The residue in the extractor is heated by the steam in the jacket, and sometimes by live steam, to remove the last traces of solvent from the meal. Both the extractor and the still are connected to a common condenser.

The problem of removing the finely suspended matter from the solvent where it is held in suspension, is one that has been the subject of much experimental work, and some plants have filtering devices attached to them. In the authors' experience, while it is possible to bring about separation of these foots by filtration, the method is not a practical one, complete filtration is very difficult, the cleaning of the filters is most troublesome, and the complete elimination of the cake formed in such filters is almost impossible. Practical experience extending over a period of thirty years has shown that the method of sedimentation is infinitely to be preferred to filtration when dealing with a solvent carrying finely divided material in suspension. The manufacture of meat meal and meat-and-bone meal from animal residues by solvent extraction follows along the lines already described for the treatment of fish offals and whole fish.

Figure No. 72 is an illustration of the extraction portion of a plant erected for the treatment of slaughterhouse offal, fresh and cooked bones and materials of a similar nature. The raw material is received on the floor above, through which pass the feeding hoppers of the extractors. The bones are submitted to a preliminary crushing prior to extraction, to render them less resistant to parting with moisture, and more readily attacked by the solvent. It is the usual practice to treat the cooked material to two or three washings with the solvent, so as to reduce the amount of oil in the residue to at least 3 per cent. As is the case with most fish residues, a certain amount of non-fatty suspended matter finds its
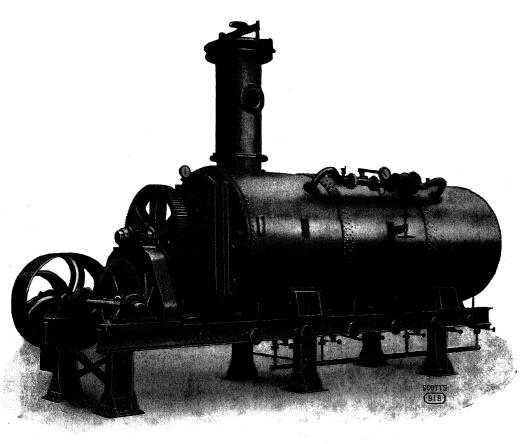
Fig. 71

HORIZONTAL TYPE OF SOLVENT EXTRACTION PLANT, PARTICULARLY SUITABLE FOR FISH BY-PRODUCTS

Courtesy of Geo. Scott & Son (London), Ltd.

[*Facing page* 234
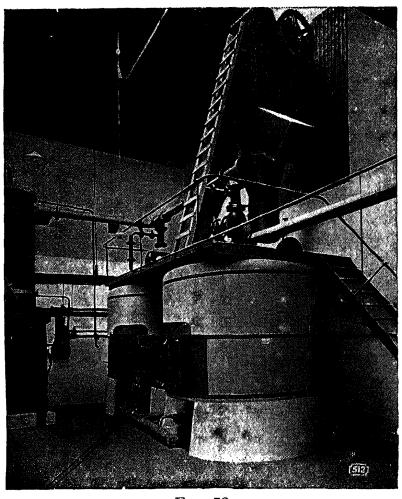
Fig. 72

A SCOTT SOLVENT EXTRACTION PLANT FOR BONES
AND OFFAL

Courtesy of Geo. Scott & Son (London), Ltd.

way along with the solvent and the fat. Consequently settling has to be resorted to, otherwise the fat delivered to the fat tanks contains much suspended matter, difficult to remove at this stage.

Fortunately meat residues do not appreciably deteriorate in colour by treatment with live steam or at temperatures slightly above the boiling point of water. The last traces of solvent can therefore be removed by direct steam treatment. This final raising of the temperature serves a further purpose—it removes the possibility of the meat being a carrier of animal diseases, a possibility arising from the handling of the carcase or offal of diseased animals. The treatment is therefore carried on for a sufficient period at a suitable temperature to bring about sterility.

Requirements of the Ideal Plant

A satisfactory extraction plant should comply with the following requirements :

1. It must produce feeding meals palatable to live stock and at the same time supply protein and mineral salts of a kind readily assimilated. They must keep in a sweet condition for an indefinitely long period.

2. The meals should possess a very low percentage of oil or fat. These substances are not good for animals in any but small quantities and furthermore meals containing a high percentage of oil will not keep for more than a few months without the development of rancidity. Then they are no longer palatable.

3. The plant must be so constructed as to remove from the meal the last trace of solvent, whether this be petroleum benzine or a halogen compound.

4. The mechanical operation of the plant must not be too complicated, otherwise highly skilled labour will be required to control it, and the cost of upkeep will be uneconomically heavy.

5. With efficient working the loss of solvent should not exceed 1·5 per cent. of the weight of raw material treated, and there are in existence to-day extraction plants in which the solvent loss is steadily maintained as low as 0·7 per cent.

6. Fuel consumption should not be more than 8 to 9 cwt. of fuel per ton of raw material treated.

7. Adequate provision should be made in the plant for the retention of finely divided material, one of the most troublesome problems that have to be faced. Excess of suspended matter in the oil leads to a lowering in market value and an increase in the free fatty acid content, because additional treatment nearly always necessitates further heating and a consequent loss of colour.

8. On occasions it may be necessary to treat materials possessing an unpleasant odour, particularly fish offals. The plant should therefore be so constructed as to prevent the escape of noxious vapours

from the cooking material. This is a difficult matter, but one manu-facturer of extraction plants has so successfully overcome it as to furnish a guarantee to the effect that if there arise any nuisance in the neigh-bourhood of the plant, which can be attributed to its faulty action, he will at his own cost re-erect the plant on any other site chosen by the meal manufacturer.

Typical Meals

The following are the average analyses of many hundreds of samples of feeding fish meal and feeding meat-and-bone meals, produced by the extraction process, the analyses having been carried out under super-vision of one of the authors. For official methods of analysis see the Fertilisers and Feeding Stuffs Act, 1926.

Fish Meal

Protein (albuminoids)	57·7 per cent.
Oil	3·6 ,,
Phosphoric anhydride	9·9 ,,
Moisture	8·4 ,,

Meat and Bone Meal

Protein (albuminoids)	52·0 per cent.
Oil	2·8
Phosphoric anhydride	14·3
Moisture	6·2

These average analyses are obtainable from raw material charges con-sisting approximately of half bone and half meaty matter. If the per-centage of meaty matter be increased then the residual meal is correspond-ingly richer in protein matter. It has been found in actual practice that packing-house animal residues average about 50 per cent. bone and 50 per cent. meaty matter. The loss through moisture from such material is approximately 50 per cent., and the yield of grease and meal from the dried residue about 38 and 62 per cent. respectively.

Nitrogenous Fertilisers

In spite of all the precautions taken in the manufacture of feeding meals, a considerable quantity of finely suspended matter gets carried over into the grease tanks from the solvent still, and are separated from the grease or oil by settlement. These " fines " are of course rich in fat, which may be recovered by treating them in the extractor, either separ-ately or mixed with the catch-pit skimmings. The residue, after extrac-tion, is comparatively free from fat or oil, and can be used for fertilising purposes. The effect of having heated and extracted these fines a second time is to render them too dark in appearance and to give them a slightly burnt flavour, so that they are no longer suitable for feeding purposes.

In those cases where the canning establishment conducts its own slaughtering, large quantities of blood will be available, which can be converted into a very highly concentrated protein feeding meal.

The blood is caught from the animal, as quickly as possible, after slaughtering, and pumped or allowed to gravitate into a steam jacketed vessel, in which it is coagulated by heat. The liquid portion is allowed to run to waste, and the clot passed to an hydraulic press where it is subjected to a sufficiently high pressure to remove much of the extraneous moisture. The pressed blood is then placed in a rendering or drying vessel, fitted with stirring gear, and dried under vacuum. The dried material is ground. Blood dried under these conditions should contain about 14·0 per cent. nitrogen, equivalent to 90·0 per cent. proteins.

If preferred the wet blood can be passed direct into the dryer. The product so produced is equal in quality to that made by the process described above, but on account of the large amount of moisture which has to be removed by the application of heat, much more steam is needed to reduce the blood to the necessary moisture content to yield a product containing the percentage of nitrogen mentioned above.

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CHAPTER XV

OUR increasing knowledge of bacteriology is showing more and more clearly how immensely important factory hygiene has become, and how large a part it plays in the successful production of foodstuffs. In the days before science was associated with the manufacture of food, the premises were often apparently quite reasonably clean so far as visible dirt was concerned, and there can be no doubt that the scrubbing and scouring which took place were of considerable benefit, for they certainly did remove visible dirt. Only comparatively recently has it become known that the greatest danger arises from bacteria and moulds which are invisible. The growth of both bacteria and moulds is greatly encouraged by allowing perishable materials to accumulate until they become stale. This danger must never be allowed to arise. Cleaning down every day at the completion of work is, of course, essential, and in any well-conducted factory is carried out as part of the daily routine. But ordinary cleaning down is quite insufficient, and it is the purpose of this chapter to point out some of the likely sources of danger, and to suggest how they can be dealt with.

Spoilage of food is caused almost entirely by the action of putrefactive bacteria. The number is legion; they exist almost everywhere—on hands and clothes of employees, on walls, floors and ceilings, in water and in the air, particularly when dust is present. As soon as they alight upon any substance which promotes their growth, they at once begin to multiply at an almost incredible rate, more especially in warmth. Except by observing the stringent precautions taken in a surgical operating theatre, it is not possible entirely to prevent a certain amount of bacterial contamination in the manufacture of foods of all kinds. The best that can be done is to aim at keeping down the number of organisms to the utmost limit by various methods, and to pay special attention to the treatment of materials which have been " sterilised " by cooking to avoid subsequent infection.

The site and lay-out of the premises are of great importance. A situation remote from waste dumps, stables, or other places which encourage the breeding of flies should be chosen, and the factory should be erected as far as is practicable from a main road or other source of dust. There must be an ample water supply of undoubted purity; too much

water cannot be used. The factory should be so designed that waste materials can at once be removed as they accumulate. It is not satisfactory to arrange for a daily removal, particularly in hot weather. In many manufacturing operations the raw material arrives on the premises in a highly contaminated condition—for example, fruit in baskets which have come by rail or road, vegetables (such as peas) straight from the fields, or livestock, which is, of course, invariably infected with fæcal matter on the feet, and often in the coat.

It is highly desirable to confine these raw materials to one department of the factory, and so to arrange the work that after the preliminary preparation the material is perfectly clean, and as far as possible, free from contamination, before it goes to other departments to be worked up into the final product. Unless precautions are taken at this initial stage, infection is likely to be carried from one department to another throughout the factory. This point must be taken into consideration in the design of the premises ; to attempt to remedy it subsequently is almost, if not quite, impossible.

Untreated raw materials should never be handled by the employees who handle goods in course of manufacture, or in the same department. In a well-designed plant, the raw materials arrive at one end, and the finished product leaves at the other ; in the course of manufacture it never doubles back, but always travels in one direction.

Condensation Troubles

The floors, walls and ceilings of all departments should be constructed of impervious substances which lend themselves to washing ; tiles, glass and marble are examples of suitable materials. There should be plenty of daylight. Corners of rooms should be rounded, so as to prevent accumulation of dirt. The use of wood should be avoided ; sooner or later it becomes impossible to keep it really clean. Where boiling in open pans takes place, much thought should be given to the troubles arising from condensation ; efficient means of removing from the room all the steam from cooking operations should be designed. Drops of moisture falling from the ceiling upon goods and utensils frequently cause infection, but are quite unavoidable unless the necessary precautions are taken to prevent condensation. Various systems are in use to deal with this trouble. It may be overcome by the use of hoppers placed over the pans, the hoppers being connected by ducts to a fan which causes a current of hot air to pick up the steam and convey it outside the premises before condensation can take place. Another system depends upon circulating a current of warm air just underneath the ceiling. This keeps the material of which the ceiling is constructed too warm for steam to condense upon it. Both methods cost money to operate, but it is money well spent ; condensation troubles can be very serious.

Tables, benches, and utensils of all kinds should be constructed of metal, preferably stainless steel; or tables may be made with metal legs and glass or marble tops. The use of wood should at all cost be avoided. Articles fitted with legs should be made so that there are no niches in which dirt or any other material can accumulate. Trolleys and trucks should be made of metal. For certain trades the use of galvanised iron is permissible, but not where there is a possibility of the foodstuff attacking the zinc and becoming contaminated with it. Although they are somewhat noisy when being moved over ribbed tiles, iron wheels for trucks are to be recommended. They are easy to clean, and will stand high temperatures without deterioration.

Where it is the custom to convey unpacked goods on movable belts, the use of canvas belting is undesirable; it is of an absorbent nature, and therefore likely to harbour bacteria. It must of necessity be washed, and is difficult to dry. Leather is to be preferred, particularly if it has been rendered impervious to moisture by treatment with bichromate or other waterproofing material. Gravity runways should be constructed with steel rollers, preferably tinned so as to avoid the formation of rust, which leads to roughened surface and to cleaning troubles. All the above details are well worth considering if cleanliness is to be the watchword.

Cleaning Routine

Premises thus equipped will readily lend themselves to a daily wash with hot water, and soap powder, and if necessary, soda for the removal of grease. The treatment of trolleys and other small utensils calls for special methods. Tables, including the legs, should be thoroughly scrubbed, the walls and ceilings hosed with a copious supply of hot water, and the floors scrubbed with hot soda water *every day*. But this is not enough. The washing of the premises should be followed by a sodium-hypochlorite spray. The soap, etc., will remove the grease and visible dirt; the hypochlorite will destroy the bacterial flora inevitably collected during the day's work. These cleaning operations appear rather formidable on first sight, but if properly organised they can be carried through in 15 to 20 minutes, provided every employee has his or her particular task allotted. It should be an invariable rule that the cleaning must be carried out as a part of the day's regular routine. Care in this direction will save pounds.

If the plant is in continuous operation during rush periods, systematic cleaning should not be neglected. It should be carried out every twelve hours, with the same care as would be given if the plant were to be left idle for some hours. When the work is not continuous, before beginning operations in the morning, table tops, etc., may with advantage be sprayed with a solution of sodium hypochlorite. This precaution is very desirable in dry weather.
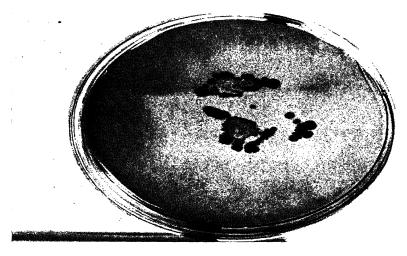
FIG. 73

THIS AND THE FOLLOWING PHOTOGRAPH SHOULD BE COMPARED.
IT SHOWS A GELATINE PLATE HEAVILY INFECTED FROM THE SWAB-
BING OF A METAL-TOPPED TABLE USED FOR CUTTING VEGETABLES

Courtesy of " Food "
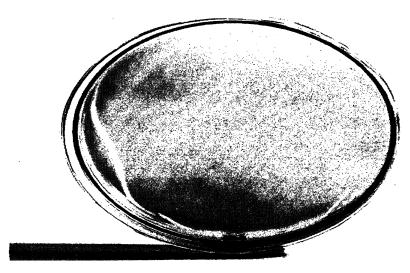
FIG. 74

THIS SHOWS THE RESULT OF A SWAB FROM THE SAME TABLE TOP AS
USED IN FIG. 73 AFTER IT HAD BEEN TREATED FOR TWO MINUTES
WITH SODIUM HYPOCHLORITE SOLUTION

Courtesy of " Food "

Movable Plant

Movable plant, such as trays, metal measures, scale pans, and trucks, should be steam-sterilised at least once every twelve hours, and more frequently if possible. Small articles can be boiled in water containing a little soda, and then treated with hypochlorite solution if they are to stand idle for long after boiling; if they are to be used immediately, they should be rinsed in clean, very hot water.

Trucks and trolleys should be treated in a sterilising cabinet. This should be constructed of brick, preferably cement-lined and insulated on the outer surface. It should be made with well-fitting sliding doors of iron, one at each end, the doorways being sufficiently large to admit the trolley easily. The cabinet is supplied with live steam under slight pressure—say, 5 lbs. per sq. inch—steam nozzles being fitted on both sides, and also at the top and bottom of the cabinet. The trolleys or trucks should first be scrubbed with soda water to remove adherent dirt, then rinsed with clean water and then placed in the steaming cabinet, where they should be left for five minutes or more. If the preliminary scrubbing has been effectively carried out, the trolleys should be perfectly clean on removal from the cabinet; and being constructed of metal, a good conductor of heat, they should dry very rapidly. It should be a definite rule that no truck or trolley should be used more than once without passing through the cleaning process. In a large factory, sterilising cabinets should be provided in every department.

Personal Hygiene

Another important matter is the personal hygiene of the employees. It should be an unalterable rule that every person engaged in the handling of foods must wash his or her hands upon arrival at the factory premises. The necessary supervision should be provided to see that this is done, and to carry out an inspection after the washing and before work is begun. Any employee leaving work to use the lavatory should wash before being allowed to return to work.

In regard to uniforms, these should be provided by the employer, and should in no circumstances be allowed to be taken off the premises. Clean uniforms, including caps for all employees, must be available as as often as needed, if necessary daily. Soiled clothing provides a suitable breeding ground for putrefactive and other objectionable organisms.

First Aid Equipment

The law demands the provision of first-aid equipment in all factories, and if it is properly organised the first-aid or accident department can be utilised for furthering the work of factory hygiene. All minor cuts, or even scratches, should receive attention; and in no circumstances

should an employee with even the smallest discharging wound be allowed to handle food, if the wound is uncovered or in such a position that it can be fingered during work. The first-aid department should be under the direction of a fully qualified hospital nurse, who can at once call in the services of a medical officer if they are needed.

Where many are employed in the same department, infectious diseases are readily spread ; it should be the duty of any employee to report to the foreman at once if any member of his or her family has contracted them. The employee should not be allowed to begin work until the medical officer has been notified, and if necessary until the period of incubation for that particular disease has elapsed. Quite apart from the danger of spreading the disease among the workers, there is a number of foods which can act as carriers of pathogenic organisms, and the trouble may be spread to other districts unless rigid precautions are at once taken.

Conditioned and Filtered Air

There are quite a number of operations in the manufacture of many kinds of foods which can most advantageously be carried out in air which is of constant humidity, of even temperature, and from which dust, mould spores, and bacteria have been removed. The conditioning of air is somewhat costly ; but, as well as the beneficial effect it has upon the quality of the goods being handled, it has a bearing upon the rate of work of the operatives. All are familiar with the enervating effect of a close and damp atmosphere due to high temperature and high relative humidity ; nor can the best work be expected from employees who are trying to carry on in a room with too low a temperature. By the use of modern air-conditioning plant, the humidity and temperature of any room may be kept constant all the year round. It is necessary only to decide upon the optimum conditions for material and workers, and to adjust the air-treatment plant accordingly. This air is as free from bacterial and mould contamination as is practically possible. If goods are wrapped and packed in conditioned air, their keeping qualities are greatly prolonged.

If conditioned air is to be installed, it must be given consideration in the design of the premises ; air currents up lift-shafts, staircases, etc., will need to be dealt with by the construction of double doors and other devices. Also different air conditions may be demanded by the materials, according to their state of manufacture. For example, a dry warm atmosphere will do much to obviate condensation difficulties mentioned earlier in this chapter.

Sodium Hypochlorite Solution

It will be gathered, from what has been written above, that sodium hypochlorite should be regarded as a supplementary cleaning agent and disinfectant. Its germicidal properties depend upon the affinity

which chlorine possesses for hydrogen, liberating oxygen which oxidises the organic matter present to harmless substances. It cannot distinguish between living organic matter, such as bacteria and moulds, and pieces of vegetable, meat or other foodstuffs; hence the need for removing all visible waste and dirt before applying the hypochlorite solution.

Sodium hypochlorite can be obtained of such a strength that it contains from 13 to 15 parts available chlorine, and in this strength needs considerable dilution before use. For general disinfection purposes, a 0·4 per cent. solution will be found effective, but where the destruction of mould is concerned, a 0·5 to 0·75 per cent. solution will be found preferable.

Walls, roofs, floors, etc., can be sprayed by the use of a machine which produces a very fine spray; but table-tops, etc., can be swabbed with the solution. It will have no harmful effect upon the foods unless these are coloured with vegetable or aniline dyes, in which event they should be kept away from the hypochlorite, which might have a bleaching effect upon the colouring matters.*

In addition to its action as a germicide, it is one of the best of all deodorants. It can also be used with advantage for the treatment of drains, for which purpose it should be employed as a solution of 5·0 per cent. strength.

The illustrations show the effect of a 0·4 per cent. solution of hypochlorite upon the surface of a metal-topped table, used for cutting up vegetables. One is of a gelatine plate showing the bacterial infection of the table-top before the application of the solution; the other, the same table-top after it had been exposed to the action of the hypochlorite for two minutes.

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* The free chlorine in the hypochlorite solution will be very rapidly destroyed, so that after a few minutes it will be without effect upon artificially coloured goods.

INDEX